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Evaluation and Documentation of the Effects of Operation and Maintenance Practices on the Performance of Selected Biological Treatment Plants

Gannett Fleming Corddry and Carpenter, Inc.
Harrisburg, PA

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EVALUATION AND DOCUMENTATION OF THE EFFECTS OF OPERATION AND MAINTENANCE PRACTICES ON THE PERFORMANCE OF SELECTED BIOLOGICAL TREATMENT PLANTS

by

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Contract No. 68-03-2571

Project Officer

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16. ABSTRACT

The purposes of this study were to evaluate operational and maintenance programs at municipal biological wastewater treatment facilities; identify all the deficiencies in the areas of design, operation, maintenance, and administration; and to determine how the deficiencies could be overcome and operations could be improved in order to upgrade plant performance to meet standards. This report deals with the second phase of the two-part study; the findings of the first phase were published in EPA reports 600/2-79-078 and 600/2-79-034. Conclusions and recommendations of the second phase were based on comprehensive evaluations conducted at 23 treatment facilities. Of 70 potential problem areas evaluated, the ten highest ranked, based on frequency of occurrence and severity of impact, were operator application of concepts and testing to process control, sludge wasting and return, process control testing, process controllability, technical guidance for process control adjustments, industrial loading, sewage treatment understanding, adequacy of O&M manual, training, and infiltration/inflow.

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EPA-287 ;Cin.)
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FOREWORD

The Environmental Protection Agency (EPA) was created because of increasing public and government concern about the dangers of pollution to the health and welfare of the American people. Noxious air, foul water, and spoiled land are tragic testimony to the deterioration of our natural environment. The complexity of that environment and the interplay between its components require a concentrated and integrated attack on the problem.

Research and development is that necessary first step in problem solution and it involves defining the problem, measuring its impact and searching for solutions. The Municipal Environmental Research Laboratory develops new and improved technology and systems for the prevention, treatment, and management of wastewater and solid and hazardous waste pollutant discharges from municipal and community sources, for the preservation and treatment of public drinking water supplies, and to minimize the adverse economic, social, health, and aesthetic effects of pollution. This publication is one of the products of that research; a most vital communications link between the researcher and the user community.

The research reported here specifically addresses the problem of poor performance of many of the nations publicly owned biological wastewater treatment plants. The existence of the problem has been documented in effluent quality surveys conducted by EPA. A Government Accounting Office study has also called attention to the problem. The objective of this research was to determine the causes for this substandard performance at apparently well designed treatment facilities. By identifying those causes it becomes possible to design specific comprehensive corrective programs to correct deficiencies at problem treatment facilities. The ultimate result of implementation of such corrective programs should be an overall improvement in effluent quality and a reduction in pollutant loadings on the nations waterways.

Francis T. Mayo, Director
Municipal Environmental Research Laboratory

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EXECUTIVE SUMMARY

Research was conducted over a two year period, beginning in 1975, that produced a list of problems felt to be the major causes of unsatisfactory performance of biological treatment plants. The findings of that research, published in two EPA reports (No. 600/2-79-078 and No. 600/2-79-034), stimulated much interest since it became apparent that there was a significant potential for plant performance upgrading through imposed operational programs. To expand the data base, and further define the priority problems, a second investigation was commenced in July 1978.

Investigations were conducted in EPA Regions II and III. Responsible state regulatory agencies within the two EPA regions were contacted by GFCC, assisted by the Chief of the Municipal Permit Programs Branch. The various agencies were requested to provide a list of candidate treatment facilities, meeting the following criteria:

1. Plants must incorporate a biological treatment process as the basic method of wastewater treatment.

2. Plants should have a history of inadequate performance as measured by effluent quality.

3. Though not restrictive, hydraulic capacities of plants should range from 1 to 5 mgd.

4. Plants should not be hydraulically or organically overloaded to any great extent.

5. No enforcement action should be presently under way against the municipality or authority involved, nor should the municipality be in the process of designing or constructing physical modifications in the treatment facility.

The lists of plants were reviewed by GFCC and 69 facilities were selected for on-site screening investigations, known as site visits. During each site visit, various preliminary data were compiled, including information relative to process schematics, wastewater characteristics, staffing, laboratory capabilities, permit requirements, and maintenance activities. Through interviews, information was solicited from the plant staff relative to specific problems interfering with plant performance. Normally, two to three site visits were performed in one day. A brief report summarizing the findings from each visit was subsequently prepared and submitted to EPA.

On the basis of the site visits, 23 of the plants were selected for more

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EPA-287 (Cin.) (4-76)

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comprehensive study under the preliminary evaluation phase. Generally, the basis for selecting a plant for study under the preliminary evaluation phase was the apparent predominance of operation and maintenance related problems, rather than design inadequacies. Evidence of inadequate staffing, process control deficiencies, improper maintenance, and insufficient funding was noted during the site visits. Also noted were major design deficiencies that could interfere with plant operability. During each preliminary evaluation, the most recent year's operating records were obtained, sampling and analysis of influent, effluent, and interprocess flows were conducted, and detailed budgetary information was obtained. In addition, operating personnel were interviewed extensively concerning many aspects of operations. In most cases, several visits to a facility were conducted during the preliminary evaluation phase. Preliminary recommendations for optimizing operations were made at the time of the initial visit and follow-up data were obtained during return visits. Reports covering findings and conclusions for each of the 23 preliminary evaluations were prepared and submitted to EPA.

Conclusions resulting from the site visit phase of the project are based on a relatively wide data base but with limited depth of investigations. Observations made during this phase of the project are as follows:

1. Most plants visited were constructed or upgraded since 1965. As such, age of the facility or equipment was rarely cited as a problem.

2. Preliminary treatment processes were provided at 70 percent of the plants. More than 75 percent of the facilities were equipped with a primary treatment stage. However, only about 15 percent of the plants included a form of tertiary treatment.

3. One-third of the plants visited reported major problems resulting from infiltration/inflow. The primary problems associated with excessive infiltration/inflow were periodic hydraulic overloads of plant units and "washout" of suspended growth biological systems. Dilution of wastewater strength and resulting upset of the biological process was also a consequence of this problem.

4. Approximately 35 percent of the plants were faced with moderate to severe problems concerning industrial wastewater discharges. Specifically, intermittent or slug organic loads from industry caused process upsets.

5. Most plants were staffed 40 to 60 hours per week. The extent of shift coverage appears to be proportional to the size of the facility.

6. Staff training at a majority of the plants was felt to be adquate on the basis of discussions with the plant operators.

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(4-76)

7. More than 85 percent of the plants reported minimal or no downtime as a result of inadequate maintenance. An adequate on-hand supply of spare parts was reported in only about one-third of the cases, although parts were usually readily available from local suppliers.

During the preliminary evaluation phase, problem areas were studied more intensively. Principal areas of investigation included plant and unit process performance, design adequacy, operation and maintenance practices, and administrative policies. As part of the investigation, a plant evaluation summary (weighting and ranking table) was prepared whereby deficiencies and problems at each facility could be assessed. This table permitted the quantitative weighing of 70 specific problem areas and the priority ranking of the highest weighted problems. The 10 most significant problems for the combined 23 plants were identified and are listed in decreasing order of severity as follows:

1 Operator Application of Concepts and Testing to Process Control
2 Sludge Wasting and Return
3 Process Control Testing
4 Process Controllability
5 Technical Guidance for Process Control Adjustments
6 Industrial Loading
7 Sewage Treatment Understanding
8 O&M Manual Adequacy
9 Training
10 Infiltration/Inflow

On the basis of this list, it is apparent that the predominant factor adversely impacting plant performance is the lack of application of process control techniques. A partial cause of this situation appears to be the inability of the operators to relate the somewhat generalized classroom training to their specific facility. Another reason is that the operators are not always willing to accept the merits of process control and, as a result, downplay the need for process monitoring. In many cases, the lack of a comprehensive O&M manual was determined to be a major deficiency which contributed to the process control problem and limited the operators ability to respond to "trouble" situations, such as process upsets.

Plant design problems, such as inadequate provision for process controllability or flexibility, and sludge handling limitations, hamper the efforts of the operators to practice effective process control. External factors, including industrial loading and infiltration/inflow, also adversely affect performance.

For the most part, maintenance practices at the 23 evaluation plants were satisfactory. It is important to note that operators in supervisory positions seemed to give first priority to keeping the plant equipment operating and maintaining good housekeeping practices, while biological process control and

optimizing plant performance as measured by effluent quality receive secondary, if any, consideration.

With respect to administrative policies, two areas were examined in detail - staffing and budgeting. Approximately one-third of the preliminary evaluation plants were staffed at a level at least 25 percent less than that recommended in EPA's staffing guidelines. Examination of the budgets for operation and maintenance indicate that a majority of the plants were allocated funds in excess of the average expenditures at a representative sampling of similar plants in their respective geographical areas. Therefore budgets were not felt to be a major direct constraint on plant performance.

A number of existing programs are helping to improve the performance of municipal treatment plants. Publications aimed at assisting the operator have been made available by EPA, state regulatory agencies, and associations, such as the WPCF. Regulations promulgated by EPA should reduce the adverse impact of industrial wastewaters and infiltration/inflow on plant performance. State certification programs have been successful in establishing a baseline level of understanding for plant operators. Training programs have been confined to government-sponsored or college-level courses, such as the Sacramento series. Plant-specific training continues tc be a seldom-used tool. Some consulting firms offer on-site, plant-specific training, although few municipalities recognize their need for such services. Comprehensive O&M manuals, where they exist, are a valuable training aid and source of reference for the operators relative to process control adjustments, troubleshooting, and conducting maintenance activities. Plant start-up services are now grant-eligible and will, no doubt, be used to a greater extent as a result. On the basis of the foregoing, it appears that much has been done to improve plant performance through operations optimization; however, considerably more effort will be required before the problems identified in this study are ameliorated.

For each of the 23 individual preliminary evaluations comprising the major effort under this project, specific recommendations for improving plant performance were set forth. These recommendations involved, for the most part, rather minor expenditures for upgrading operational, maintenance, and administrative programs. Considering the data compiled during the survey, the percentage of plants currently complying with BOD_5 and suspended solids effluent limits was found to be only 55 percent and 64 percent, respectively. With the implementation of the recommended program changes, it is estimated that BOD_5 and suspended solids limitations compliance would improve to 86 percent and 95 percent, respectively. Costs associated with the implementation of preliminary evaluation recommendations at three typical facilities were estimated. Based on these estimates, initial-year costs could be expected to range from approximately $10,000 to $50,000, whereas annually recurring costs would be in the range of $2,000 to $10,000. These cost estimates are given only to illustrate the order of magnitude of costs associated with a composite operations correction program. Each case will be unique in its scope and required expenditures. However, the figures given indicate the cost effectiveness of attaining effluent quality objectives through operations optimization, as opposed to achieving permit compliance through other means such as costly construction or addition of capital equipment. In fact, court imposed fines

for non-compliance would most likely exceed the entire cost of a composite operations correction program.

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CONTENTS

		Page
Foreword		iii
Executive Summary		iv
Figures		x
Tables		xii
Acknowledgement		xiii
1.	Introduction	1
2.	Conclusions	2
3.	Recommendations	5
4.	Research Approach	7
5.	Discussion of Site Visit Findings	13
6.	Evaluation of Causes of Limited Performance	23
7.	Impact of Established Programs on Priority Causes of Limited Performance	40
8.	Potential for Improved Plant Performance	47
9.	Cost of Implementation of Programs for Improved Plant Performance	54
10.	Comparison of Project Findings and Conclusions	58
References		60
Appendices		
A.	Summary of Site Visit Data	62
B.	Plant Evaluation Summary Composite	68

BEGIN LAST LINE OF TEXT
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BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS

PAGE NUMBER
EPA-287 (Cin.)
(9-76)

FIGURES

Number		Page
1	Relative Number of Plants with Respect to Design Flow	13
2	Relative Number of Plants with Respect to Facility Type	14
3	Relative Number of Plants with Respect to Present Average Flow	15
4	Relative Number of Plants with Respect to Year of Most Recent Upgrading	16
5	Relative Number of Plants with Respect to Supplemental Treatment	17
6	Relative Number of Plants with Respect to Infiltration/ Inflow Problems	17
7	Relative Number of Plants with Respect to Industrial Waste Problems	18
8	Relative Number of Plants with Respect to Staff Coverage	18
9	Relative Number of Plants with Respect to Staff Training	19
10	Relative Number of Plants with Respect to Process Control	20
11	Relative Number of Plants with Respect to Downtime Due to Inadequate Maintenance	21
12	Relative Number of Plants with Respect to Spare Parts Inventory	21
13	Relative Number of Plants with Respect to References for Maintenance	22
14	Present Average Flow as a Function of Design Flow	27
15	Present Average BOD_5 Loading as a Function of Design BOD_5 Loading	28
16	Operation and Maintenance Performance Indicators - Plant Laboratory	32

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD, BEGIN SECTIONS HERE

FIGURES (Cont.)

Number		Page
17	Operation and Maintenance Performance Indicators - Process Control Procedures	33
18	Operation and Maintenance Performance Indicators - Operation and Maintenance Manual	34
19	Operation and Maintenance Performance Indicators - Routine Maintenance	36
20	Operation and Maintenance Performance Indicators - Emergency Maintenance	37
21	Comparison of Actual Plant Staffing and Recommended Plant Staffing	38
22	Comparison of Actual O&M Costs with Computed Costs	39

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3/8"

PAGE NUMBER
EPA-287 (Cln.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD BEGIN SECTIONS HERE

TABLES

Number		Page
1	Priority Listing of Causes of Limited Performance	23
2	Distribution of Plants with Respect to Noncompliance with NPDES Permit Standards	48
3	Current Annual Effluent Characteristics of Preliminary Evaluation Plants	49
4	Discharge Pollutant Loads Based on NPDES Permit Levels and Present Average Annual Flow	51
5	Effluent Characteristics Attainable Through Implementation of Recommendations	52
6	Summary of Improved Performance	53
7	Composite Plant Evaluation Summary (Both Contracts)	59

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3/8"

PAGE NUMBER
EPA-287 (Cin.)
(4-7C)

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SECTION 1

INTRODUCTION

This report presents the results of a study performed under EPA Contract No. 68-03-2571, "Evaluate and Document the Effects of Operation and Maintenance Practices on the Performance of Selected Biological Treatment Plants." The project constituted Phase II of a two part study. Phase I was performed during 1975 through 1978 to determine the impact of various operational and maintenance practices on performance of biological treatment plants (EPA Contract No. 68-03-2223). The earlier study involved the in-depth field analysis of 30 biological treatment plants, and a lesser degree of data collection at 90 others. Results of the investigation showed convincingly that operational and maintenance factors were instrumental in effecting unsatisfactory effluent quality at the selected study sites. The major shortcoming was the lack of application of biological treatment concepts to process control. Correlations between operational problems and administrative deficiencies were evident. Contract No. 68-03-2223 was limited in scope to four states within EPA Region III. A parallel Phase I study was conducted in the western United States (EPA Contract No. 68-03-2224) and the major conclusion of that study substantiated operational limitation of biological treatment plant performance. Contract No. 68-03-2571 is also limited to the Eastern United States while another contractor is conducting a parallel Phase II study in the West.

The work done under these previous studies indicated significant potential for improved treatment plant performance through non-capital intensive programs exists. Further study was felt desirable so that significant previous conclusions could be strengthened or modified, and thus the investigation reported herein was initiated.

The current project was structured similarly to the previous project because the methodology had proven effective for efficiently collecting the required data. Basically one-day site visits were employed to screen candidate study plants, and 23 plants were selected for in-depth preliminary evaluations. Operational, maintenance, design, and administrative data were collected during each preliminary evaluation. Plant performance data were monitored intermittently for several months to observe effects of implementation of any preliminary operational recommendations.

The data analyzed for the 23 preliminary evaluation plants permitted the structuring of a list which ranks factors adversely affecting treatment plant performance. This list, together with the similar lists which evolved from the previous studies, points out the areas which must be given priority in the development of programs to improve treatment plant performance.

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(4-76)

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SECTION 2

CONCLUSIONS

The major conclusions forthcoming from this study substantiate findings reported for the Phase I investigation, "Evaluation Of Operation And Maintenance Factors Limiting Biological Wastewater Treatment Plant Performance" (EPA-600/$_2$-79-078). Generally, it was determined that the major causes of performance problems at the biological wastewater treatment plants studied involved a combination of improper or inadequate operational, maintenance, and administrative practices. In some cases, design errors, deficiencies, or limitations were also significant. For the most part, however, operational shortcomings were cited as the prime reason for the inability of treatment facilities to meet permitted effluent limitations. The more frequently encountered operational causes of inadequate performance were found to be:

1. Control methodologies and process testing results were not applied in formulating the strategy to control the biological process.

2. Plants monitored their influent and effluent in accordance with permit requirements but ignored process monitoring. Basic process control parameters, including MLSS, SVI, F/M, and MCRT were typically not monitored on a regular basis.

3. The lack of adequate process control testing was not the result of a need for capabilities in this area. Plant laboratories were well equipped and laboratory personnel were familiar with proper testing procedures.

4. Technical guidance for controlling the biological process was less than adequate, especially at the smaller facilities. O&M manuals were not comprehensive and frequently did not address process monitoring and control techniques. Consultant services were rarely used for operations assistance.

5. Operator training programs were often too general and were normally addressed toward a large audience. Plant-specific training was practically non-existent.

Some plants were being operated under handicaps imposed on them during the design or construction phases. The following design-related problems were observed.

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EPA-287 (Cln.)
(4-76)

1. In smaller plants, sludge return and wasting systems often limited the operator's ability to control the biological process, resulting in performance problems.

2. Industrial loading in the form of excessive compatible pollutants, such as BOD and suspended solids, frequently caused process upsets or hampered process control efforts on the part of the operator.

3. Infiltration/inflow, while not a widespread problem as was the case in the previous project, continued to plague a few plants causing periodic hydraulic overloading.

Maintenance practices were examined and their impact on plant performance was evaluated. Conclusions relative to plant maintenance are:

1. Routine maintenance was adequate at most plants. More emphasis was usually placed on maintenance than on process control.

2. Extensive spare parts inventories were not always necessary since frequently needed parts could usually be obtained from local suppliers, resulting in no significant downtime.

3. Delivery time for major equipment items not frequently needed was often on the order of months, resulting in extended periods with units out of service.

4. Overall, capabilities for dealing with emergency maintenance situations were marginal to adequate.

Study conclusions relating to administrative inadequacies or limitations were as follows:

1. Approximately one-third of the plants evaluated were staffed at a level at least 25 percent less than that recommended by EPA guidelines.

2. When compared to a large sampling of plants in the regions where the evaluations were performed, budgeting for operations and maintenance at the plants studied was above average.

Recently, more attention has been directed toward the problems of plant operations. In the past, emphasis was placed on disseminating information regarding plant design and construction, primarily from government agencies, associations, and manufacturers to those in the consultant, industrial, or construction communities. More information regarding plant operation, main-

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tenance, and administration is now being developed and distributed. Government agencies and professional associations, such as EPA and the Water Pollution Control Federation (WPCF), have made numerous publications, training sessions, and seminars regarding these topics available to the audience that has the greatest need - the plant operators. To date, however, this information is not being applied by the plant personnel to day-to-day operations. Programs which were developed by EPA and would (directly or indirectly) reduce the impact of industrial wastes on the municipal treatment plant, such as pretreatment standards, industrial cost recovery, and user charge programs, have not yet produced the desired effect, as noted during many of the evaluations. Operator training courses, offered through professional associations, local colleges, and state certification programs, have provided a basic level of knowledge to the operator regarding process control, laboratory practices, and maintenance, but have not been successful in providing the needed plant-specific training. Some consultants offer specialized, plant-specific training and operations assistance, although this service is not widely used. O&M manuals are often deficient in several respects and rarely reflect input from the plant operating staff. Operators, therefore, often do not make use of these manuals, especially to provide guidance for process control strategy.

As a part of each preliminary evaluation, specific recommendations were made for improving plant performance chiefly through nonstructural modifications, addressing areas such as training, process monitoring and control, O&M manual preparation, staffing, and budgeting for plant operations. The actual long term impact of implementing these recommendations is not known. However, on the basis of engineering judgement an estimate of attainable wastewater quality at each plant was developed. On the basis of these estimates, compliance with NPDES permit limitations by the plants would improve from 55 percent to 86 percent for BOD_5 and from 64 percent to 95 percent for suspended solids, strictly as a result of implementing the recommended operational improvements.

A final and important conclusion of this study relates to the cost effectiveness of implementing a composite correction program to improve operation and maintenance, and thereby upgrade plant performance. Estimates made on a selected sampling of plants indicated the initial cost of implementing such a program ranged from $8,000 to $46,500. Estimated annual costs ranged from $2,000 to $10,000. When viewed relative to the total investment already made in construction and operation of these treatment plants, the costs of the composite correction program appear easily justifiable considering the benefits of improved plant efficiency and better effluent quality to be gained.

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SECTION 3

RECOMMENDATIONS

In this report, the specific causes responsible for inadequate performance levels at municipal biological treatment plants are discussed. The findings and conclusions, set forth in the preceding section, were made on the basis of 23 detailed evaluations performed at typical plants located within EPA Regions II and III. According to the conclusions, considerable potential exists for improving the performance of these plants and similar facilities throughout the nation by improving and optimizing operational, maintenance, and administrative procedures. In this section, specific recommendations are offered to move toward the goal of improved plant performance and water quality. Since this was the second consecutive study of this type performed by this contractor, and since the conclusions of the earlier study were confirmed to a large degree by the findings of this undertaking, many of the recommendations offered parallel those set forth under fulfillment of Contract No. 68-03-2223. This situation serves to emphasize the urgent need for positive action in certain areas to upgrade plant operations and maintenance. Our recommendations are as follows:

1. Training programs for wastewater treatment plant operators, whether from government, professional association, or consultant sources, should emphasize in the strongest possible terms the importance of process control in maintaining optimum plant performance.

2. Because many operators appear to have difficulty relating classroom process control training to their individual plants, a greater portion of training effort should be devoted to on-site, plant-specific instructions.

3. Regulatory enforcement policy should be revised to require monitoring of various process control parameters. Such a requirement might result in more conscientious effort toward rational process control.

4. A greater effort should be made to encourage municipalities to take advantage of the services of consultants or other specialists in the area of treatment plant operations. Expanding existing federal and state financial assistance programs to cover some costs associated with retaining such experts would serve as an incentive to municipalities.

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PAGE NUMBER
EPA-287 (Cin.) (4-76)

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5. O&M manuals for existing facilities should be modified and made more complete, most notable in the area of process control. Considerable attention must be given to the intended audience for a manual, particularly in terms of vocabulary, sentence structure and example computations. Furthermore, intensive training of the plant staff with respect to use of the manual must accompany its preparation. To the extent it is possible, the plant staff should be used and consulted in upgrading the manual and trained in its use.

6. Consideration should be given to making the preparation of comprehensive O&M manuals for existing facilities grant-eligible. Costs associated with this type of service are often significant and cannot be covered in the waste treatment budget of small municipalities.

7. Stricter enforcement of existing municipal wastewater ordinances should be required to control the impact of industrial discharges on the treatment plant. Promulgation and enforcement of federal pretreatment standards will be of benefit in this regard.

It has been established through this and the previous study that inadequate performance of municipal wastewater treatment plants is not entirely the result of operational, maintenance, or administrative shortcomings. Some installations are hampered by physical constraints, and even given the benefit of operation and maintenance optimization, would be incapable of producing an acceptable effluent. However, on the basis of this study, the vast majority of existing facilities that are currently violating permit limits could be brought into compliance through improved operation. With this thought in mind, it is recommended that a prerequisite to any major, federally assisted physical modifications to a municipal treatment plant would be to conduct an evaluation, similar to that performed at the 23 plants under this contract. During such an evaluation, the actual need for physical modifications could be assessed, along with the potential improvement to be gained through optimizing operation, maintenance, and administrative practices. In this manner, expenditures for upgrading treatment facilities could be reduced where it is determined that a sufficient improvement in performance could be achieved solely through nonstructural modifications and/or minor design improvements. Some of the funds that would have been expended for the physical upgrading project could then be diverted to help cover the cost of a well developed composite correction program.

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SECTION 4

RESEARCH APPROACH

In this section our research approach will be discussed. This discussion will be broken down into two subsections, dealing respectively with the research approaches employed for the site visit phase and for the preliminary evaluation phase. This investigation was structured similarly to the Phase I biological treatment plant study, with some exceptions as discussed in the following paragraphs.

SITE VISITS

The purpose for conducting site visits was to obtain basic plant data to screen treatment plants which were available for detailed study. Findings of the site visits were used as the basis for selection of those plants which would be the subjects of the comprehensive preliminary evaluations. Because of the short duration of each site visit, minimal data was collected in this phase. To the extent data were collected, however, they were summarized and analyzed.

The procedure for selecting treatment facilities for initial site visits was based on coordination among the EPA regional offices (Regions II, III, IV, V), state regulatory agencies, and GFCC. State agencies were asked to submit lists of treatment plants meeting several criteria to the respective EPA regional offices. Considering the study objectives, the criteria deemed desirable for a treatment plant to be investigated were:

1. The treatment system be based on a biological process; including both suspended growth and fixed film systems.

2. Plant design capacity should preferably be in the range of 3,785 to 18,925 m^3/d (1.0 to 5.0 mgd.).

3. Plant should not have significant design deficiencies or a history of organic or hydraulic overloading.

4. The plant should not be in the process of designing or constructing additions to the facility.

5. The plant should have documented performance problems through repeated violations of the discharge permit.

The lists developed by EPA and the state agencies were reviewed by GFCC,

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and arrangements were made to visit selected plants in regional groupings. Depending on size of facility, type of treatment process, and plant location, the duration of each site visit ranged from one-half to one day. Normally, a site visit consisted of a complete tour of the treatment facilities in the company of the superintendent and an interview with appropriate plant staff. Information gathered during the site visits was divided into six major categories: general information, treatment facilities, operation, laboratory, maintenance, and miscellaneous problems. The nature and extent of information collected within each of these categories is as follows:

General Information

Name of treatment facility, type of facility, design hydraulic capacity, population presently served, present average daily flow, present peak flow rate, infiltration/inflow problems, volume of industrial wastewater, type of industries discharging to system, date plant was first constructed, date of most recent expansion or upgrading, name of receiving body of water, NPDES permit limitations or criteria, and state permit limitations or criteria.

Treatment Facilities

List of unit processes for wastewater treatment, list of unit processes for sludge treatment, method of ultimate sludge disposal, schematic diagram of facilities, and process flexibility.

Operation

Owner of treatment facility, operator of treatment facility, plant staffing, plant personnel, training programs, and engineering consultation.

Laboratory

Location of laboratory, laboratory equipment, testing capabilities, testing commonly conducted, suitability of laboratory records, sampling facilities, and extent of use for process control.

Maintenance

Downtime due to inadequate maintenance, spare parts inventory or accessibility, back-up units for major processes, general appearance of plant and grounds, emergency power source, references, percent of work done by outside contractors, and extent of maintenance records.

Problems

Design problems, hydraulic or organic overload, staffing problems, budgetary problems, operational problems, inability to meet permit limitations consistently, and other problems observed or identified by the operator.

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Following each visit, a report was prepared which summarized the information collected during the site visit, noted the problems as stated by the superintendent, and recommended or rejected the facility for further study in the preliminary evaluation phase. As a means of quantifying the data collected during the site visits, each plant characteristic was assigned a numerical value according to the following key:

Rating	
3	Plant is deficient in this area. Capability is nonexistent. Considerable problems result.
2	Plant may be deficient in this area. Capability is inadequate. Some problems result.
1	Plant may be deficient in this area. Capability is marginally adequate. Little or no problems result.
0	No apparent deficiencies exist. Capability appears adequate. No problems are apparent.

A tabulation of the data collected throughout the site visit phase of the project is included as Appendix A.

PRELIMINARY EVALUATIONS

The purpose of the preliminary evaluation phase was to examine in detail design, operation, maintenance, and administration of 23 treatment plants selected from the site visit phase. The results of such examination were to be a ranking of problems causing poor plant performance, and specific recommendations for improving effluent quality.

After selection of a plant as the subject of a detailed preliminary evaluation, arrangements and authorization to conduct the field work were made by contacting the municipal authority, the plant superintendent, and the authority's consulting engineer. As a rule, after the scope and objectives of the research project were explained to the concerned parties, full cooperation was extended. The 23 preliminary evaluations were conducted over the period from March 1978 to November 1978.

The typical preliminary evaluation included three days of field work. These plant visits were spaced about one month apart. This procedure differed from the earlier investigation and offered two advantages over doing the field work in three consecutive days. First, preliminary recommendations for improved operation could be made at the time of the initial visit, monitored by telephone contact, and modified or improved during subsequent

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visits. Second, the performance of the plant could be monitored during the survey period, and improvements resulting from operational modifications could be documented. Of course, even with this extended evaluation procedure, only short-term response to operational techniques could be observed. The manpower required for a preliminary evaluation was a function of the size and complexity of the plant, but normally only one man was required. Investigators were engineers with experience as certified treatment plant operators.

During a typical preliminary evaluation survey, the field personnel performed the following tasks:

1. Obtain plant monitoring records for year preceding site visit. Whenever possible, records included results of both process control and performance monitoring.

2. Whenever necessary, conduct field sampling, and analysis to supplement plant records. Examples of field tests included pH, dissolved oxygen, and settleable solids.

3. Complete the Plant Evaluation Summary (Weighting and Ranking Table). This table provides the means for subjectively quantifying design, operation, maintenance, and administrative problems experienced at the treatment facility. Design factors, operation, maintenance, and administrative programs and practices are assigned a value from 0 to 3 which corresponds to decreasing degrees of quality and completeness and increasing adverse effect on plant performance.

4. Complete, or obtain previously completed, EPA Form 7500-5 (Report on Operation of Wastewater Treatment Plant). When completed previously by EPA personnel, this form contained usable information regarding operation and maintenance practices.

5. Examine present plant staffing noting distribution of labor efforts in the work categories of management, operation, maintenance, and laboratory.

6. Gather specific information on analytical capabilities including available laboratory equipment, sampling techniques, testing methods, test frequencies, and analytical records.

7. Observe process control techniques employed by operating staff.

8. Obtain basic design information for major unit treatment processes, including tank sizes, detention times, overflow rates, and loadings.

9. Obtain copies of National Pollutant Discharge Elimination System (NPDES) permit and state regulatory agency permit.

10. Secure copy of wastewater treatment budget or most recent record of expenditures.

11. Address specific questions to plant superintendent regarding maintenance practices to supplement information obtained during the site visit.

12. Review available operation and maintenance manual and similar references for content, including equipment information, maintenance schedules, laboratory and process control techniques, parts procurement, and as-built plans.

13. Throughout the survey, monitor plant performance and make preliminary recommendations for improving or modifying operational practices.

Upon completion of the field investigations, a preliminary evaluation report was prepared which set forth the findings of the survey, and evaluated the plant in terms of performance, design adequacy, operation and maintenance, and administrative procedures. The following items were included in each report:

1. A summary of plant influent and effluent quality, as well as individual unit treatment process loadings and operating parameters. Also, the plant effluent data were computed in terms of 7- and 30-day average concentrations for purposes of comparison with NPDES permit requirements. These data were compiled for the year's operation previous to the survey.

2. Results of analyses on any wastewater and sludge samples collected during the survey. Tests typically conducted included BOD_5, various solids examinations, fecal coliform, and nutrient analyses.

3. Comparison of plant design information with conventional design standards. References for such standards were the EPA process design manuals, various wastewater treatment technology texts, and GFCC experience.

4. Comparison of plant performance data, using both the plant operating records and the results of the evaluation survey tests, with NPDES and state permit requirements.

5. Comparison of individual unit process performance parameters with accepted operating standards (i.e., primary clarifier

efficiencies, overflow rates, detention times, MLSS concentrations, food-to-microorganism ratios, and mean cell residence times).

6. A determination of optimum staffing levels in accordance with the EPA report, "Estimating Staffing for Municipal Wastewater Treatment Facilities." The actual staffing at each plant was compared with the recommended levels.

7. Comparison of plant O&M costs with estimates for plants of similar size and type as presented in the EPA document. "Analysis of Operations and Maintenance Costs for Municipal Wastewater Treatment Systems".

8. Conclusions and recommendations for improving performance. Recommendations were made for optimizing operation and maintenance practices, improving staffing and budgetary conditions, and making minor physical modifications.

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SECTION 5

DISCUSSION OF SITE VISIT FINDINGS

As described in Section 4, the site visit phase of the project involved the compiling of information from a larger number of plants (68) than the preliminary evaluation phase. Since the purpose of the site visits was to select plants for further study, the information obtained was less comprehensive than that compiled under the evaluations. Nevertheless, certain general trends and conclusions may be elicited from the broadly based site visit data. Thus, these data are discussed in this section.

GENERAL INFORMATION

Relative Number of Plants with Respect to Design Flow (Figure 1)

The largest percentage of plants were designed for average daily flows in the 3,785 m^3/d (1.0 mgd) to 9,462 m^3/d (2.5 mgd) range. The second largest fraction of plants was in the 9,462 m^3/d (2.5 mgd) to 19,285 m^3/d (5.0 mgd) range. One of the selection criteria was that the plant design flow should range from 3,785 m^3/d (1.0 mgd) to 19,285 m^3/d (5.0 mgd), since it was desired that the data base for this study be representative of the majority of the nation's treatment plants.

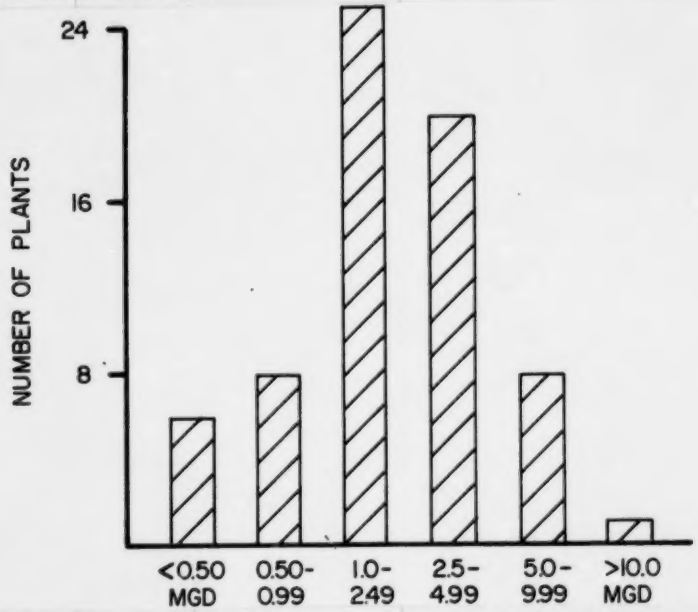

Figure 1. Relative Number of Plants with Respect to Design Flow

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Relative Number of Plants with Respect to Facility Type (Figure 2)

Both trickling filter and activated sludge plants were included in the site visit phase. Three plants employed both the trickling filter and activated sludge processes.

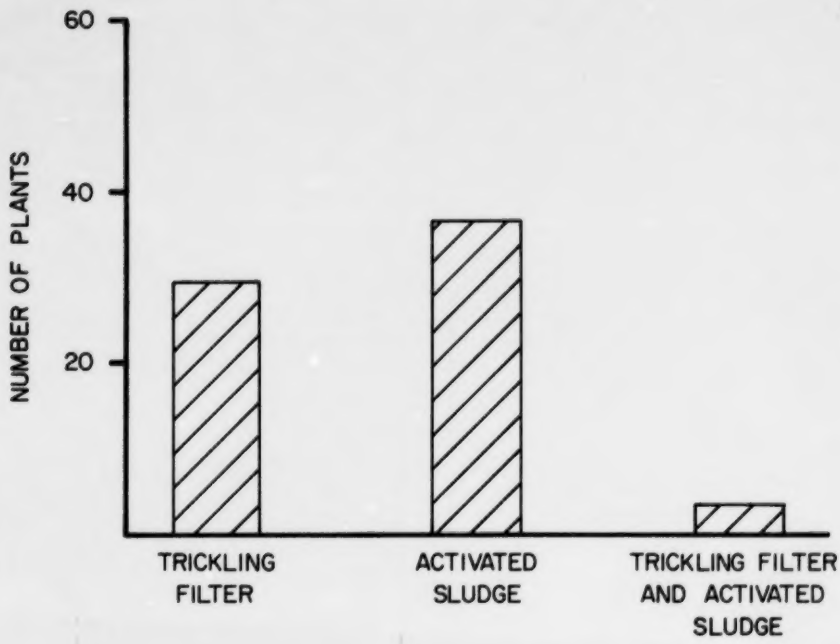

Figure 2. Relative Number of Plants with Respect to Facility Type.

Relative Number of Plants with Respect to Present Average Daily Flow (Figure 3)

The majority (75%) of the plants were receiving wastewater flows ranging from 3,785 m^3/d (1.0 mgd) to 19,285 m^3/d (5.0 mgd). Again, this was in accordance with experimental design.

Relative Number of Plants with Respect to Year of Most Recent Upgrading (Figure 4)

The vast majority of plants have been newly constructed or upgraded since 1965. Most of the construction since 1965 involved upgrading of existing primary plants to provide secondary treatment. As a result, in relatively few cases were any plants adversely affected because of the age of the biological portion of the facility.

Relative Number of Plants with Respect to Supplemental Treatment (Figure 5)

Of the 69 site visit plants, approximately 70 percent included prelimi-

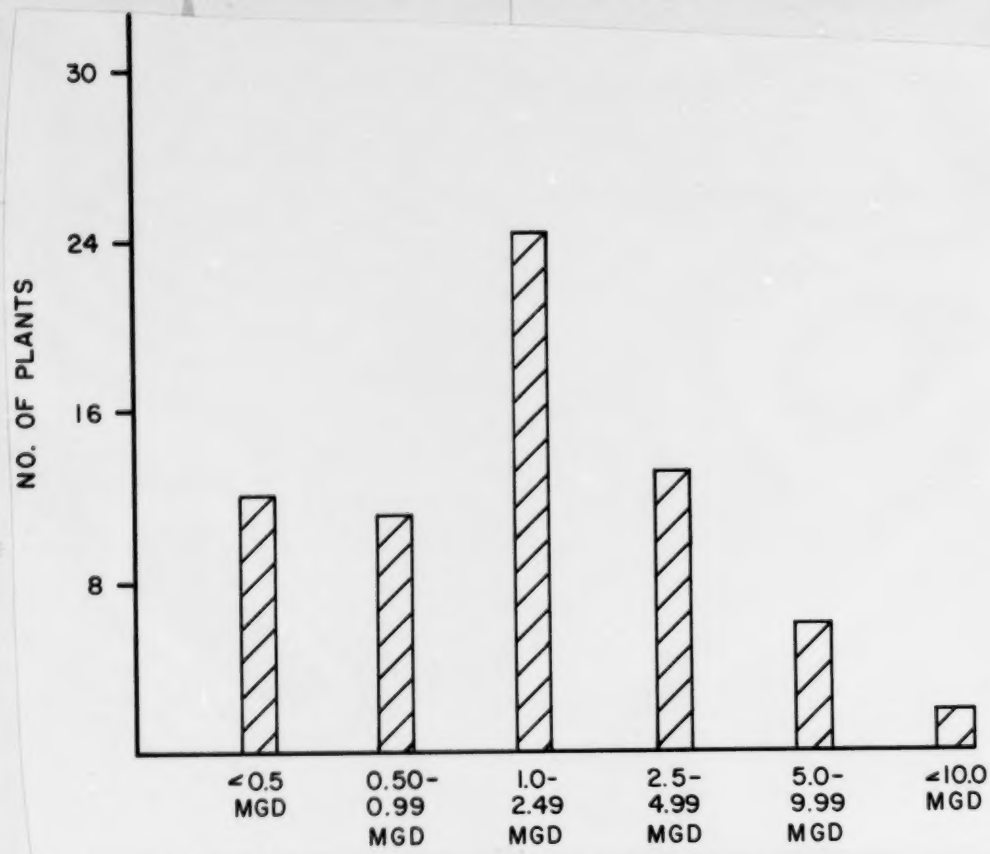

Figure 3. Relative Number of Plants with Respect to Present Average Daily Flow

nary treatment (grit removal, screening, comminution, etc.), more than 75 percent included primary clarification, and about 15 percent included some form of tertiary treatment, usually granular media filters or polishing lagoons. Performance of the biological system can be enhanced when preliminary or primary treatment precedes. Similarly, the use of tertiary processes can compensate for a poorly performing biological system by "polishing" the effluent.

Relative Number of Plants with Respect to Infiltration/Inflow Problems (Figure 6)

Major performance problems resulting from excessive infiltration/inflow were noted at one-third of the plants visited. Inasmuch as more than 90 percent of the plants visited were reported to be at least minimally affected by infiltration/inflow, the widespread nature of the problem to varying degrees is evident.

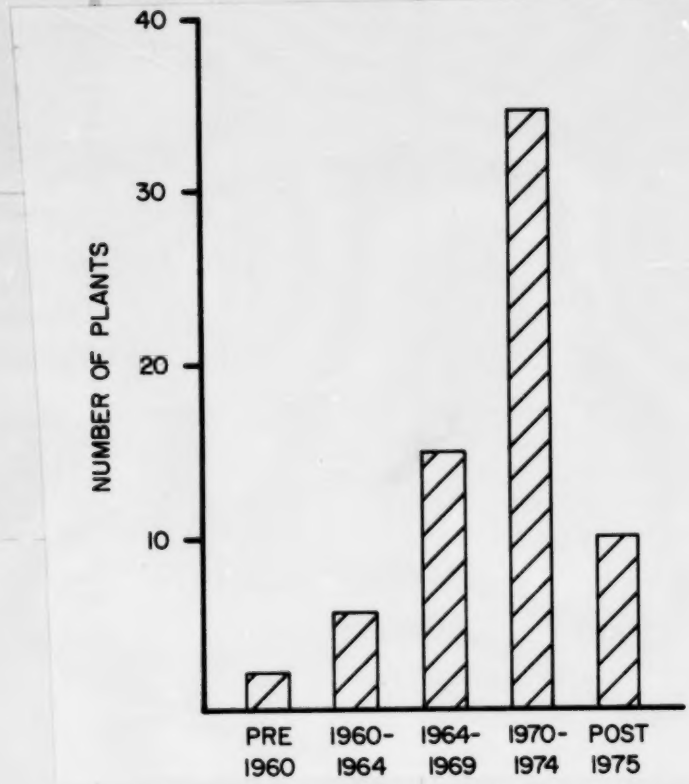

Figure 4. Relative Number of Plants with Respect to Year of Most Recent Upgrading

Relative Number of Plants with Respect to Industrial Waste Problems (Figure 7)

Industrial wastewaters in the treatment plant influent presented a moderate to severe problem at approximately 35 percent of the site visit plants. In general, the presence of industrial wastes was not reported to be a known major contributor to poor plant performance.

OPERATION

Relative Number of Plants with Respect to Staff Coverage (Figure 8)

Most plants investigated in the site visit phase were found to be staffed for a period of 40 to 60 hours per week. A very small percentage of the plants were staffed less than 40 hours per week. Nearly one-third of the site visit plants provided staffing in excess of 100 hours per week and full-shift coverage was frequently provided at the larger facilities. The data indicate that the extent of staff coverage is a function of the size of the facility and the ability to maintain the necessary personnel. It is evident that the smaller plants do not normally have benefit of full shift coverage, although the justification for such coverage may exist.

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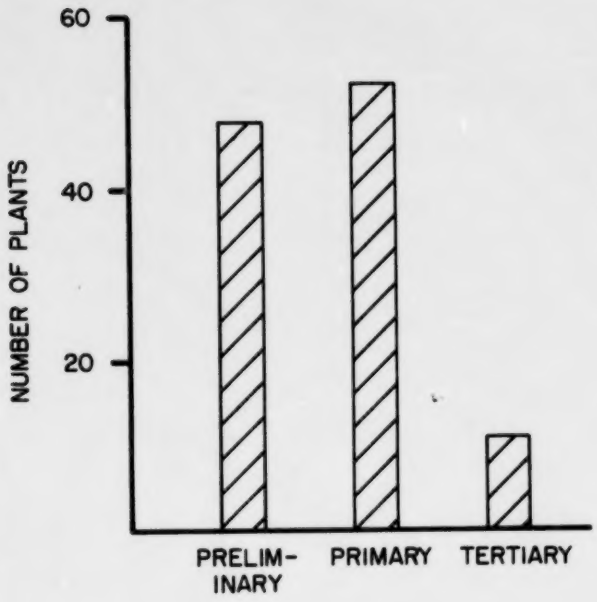

Figure 5. Relative Number of Plants with Respect to Supplemental Treatment

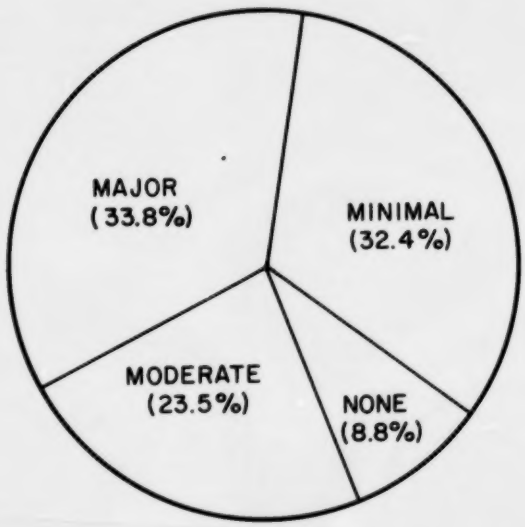

Figure 6. Relative Number of Plants with Respect to Infiltration/Inflow Problems

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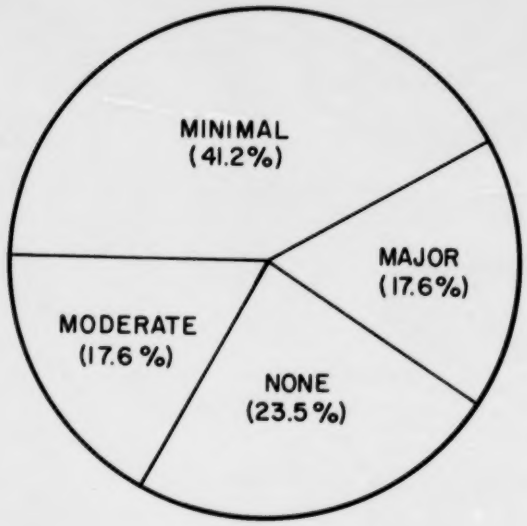

Figure 7. Relative Number of Plants with Respect to Industrial Waste Problems

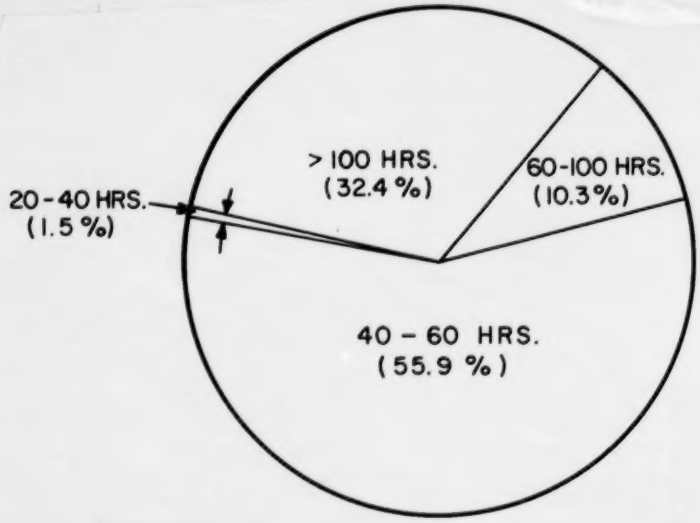

Figure 8. Relative Number of Plants with Respect to Staff Coverage

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Relative Number of Plants with Respect to Staff Training (Figure 9)

On the basis of discussions with the operators at the site visit plants, it appeared that insufficient level of operator training was not a widespread problem. Nearly three-fourths of the staffs were judged to have received an adequate level of training. It is important to note, however, that because of the relatively brief nature of the site visits it was often difficult to assess the quality of staff training with any degree of confidence.

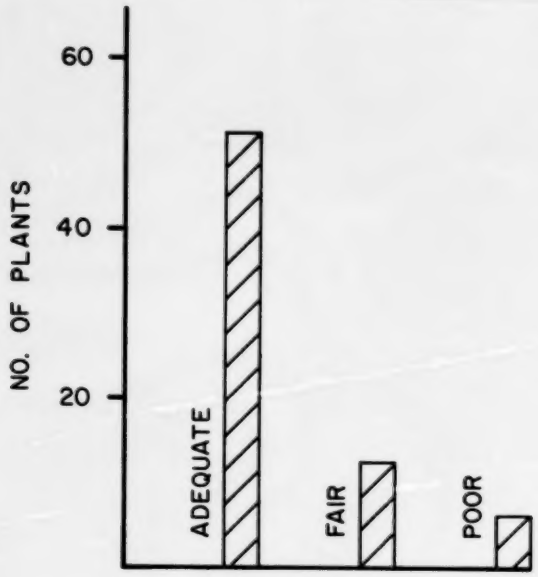

Figure 9. Relative Number of Plants with Respect to Staff Training

Relative Number of Plants with Respect to Process Control (Figure 10)

The level of process control was reported to be adequate in nearly two-thirds of the plants investigated during the site visit phase. Based on the findings of the preliminary evaluation phase of the previous project, after detailed study the lack of process control was cited as the major cause of performance problems at the 30 plants examined. In light of this fact, it is questionable that the quality of process control, as practiced at the site visit plants, is as satisfactory as was immediately indicated. Again, because of the brief duration of each site visit, process control information obtained could not be substantiated by observing control practices. Therefore, site visit conclusions relative to process control must be viewed with caution.

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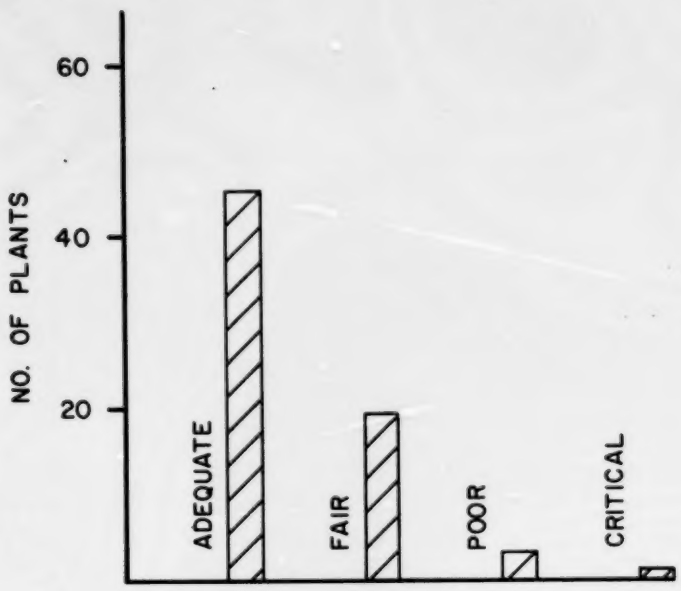

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Figure 10. Relative Number of Plants with Respect to Process Control

MAINTENANCE

Relative Number of Plants with Respect to Downtime Due to Inadequate Maintenance (Figure 11)

Excessive plant downtime, as evidenced by one or several treatment units being out of operation for an extended period, was reported at only three of the 69 plants investigated during the site visit phase. Accordingly, more than 85 percent of the plants reported minimal or no such extended downtime periods and noted that the cause of any downtime was usually an inability to procure needed parts.

Relative Number of Plants with Respect to Spare Parts Inventory (Figure 12)

Only approximately one-third of the site visit plants were noted as having an adequate supply of frequently needed spare parts. However, most plants indicated that parts were readily obtainable from local suppliers and, for that reason, were not stocked at the plant. This ready availability of spare parts is substantiated by the relatively infrequent loss of treatment due to equipment downtime.

Relative Number of Plants with Respect to References for Maintenance (Figure 13)

Maintenance references at the plants investigated in the site visit phase

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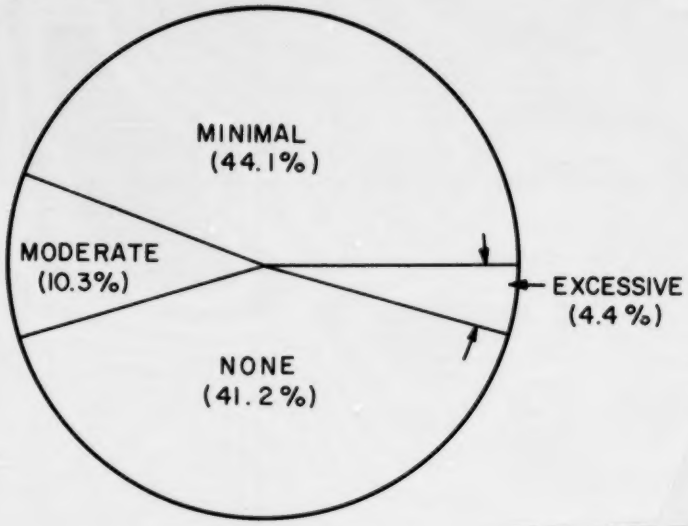

Figure 11. Relative Number of Plants with Respect to Downtime Due to Inadequate Maintenance

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Figure 12. Relative Number of Plants with Respect to Spare Parts Inventory

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were generally adequate. Such references typically included information from the equipment manufacturers and occasionally included comprehensive O & M manuals prepared by a consultant for the plant. In seven cases, inadequate references for maintenance was reported to be a cause of performance problems.

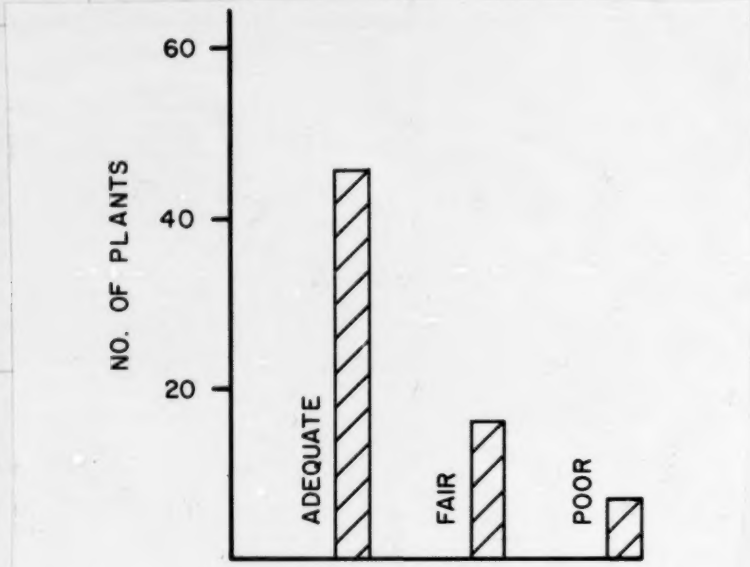

Figure 13. Relative Number of Plants with Respect to References for Maintenance

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SECTION 6

EVALUATION OF CAUSES OF LIMITED PERFORMANCE

A principal output of the preliminary evaluation phase of this project was a quantitative examination of various wastewater treatment plant characteristics. During the preliminary survey, each of seventy specific characteristics in the four major evaluation areas - design, operation, maintenance, and administration - was evaluated at the 23 plants. A Plant Evaluation Summary (Weighting and Ranking Table) which quantifies the impact of these characteristics was completed for each facility. By combining the information from each Plant Evaluation Summary, an aggregate ranking of factors most adversely affecting the overall performance of these plants was evolved.

PRIORITY CAUSES OF LIMITED PERFORMANCE

Table 1 presents a priority listing of the ten factors which most frequently and adversely affected the performance of the 23 plants surveyed. The total number of points assigned to each of the problem areas, which indicates the relative severity of the problem, and the number of times that each factor was determined to be the most critical cause of treatment problems are also indicated. Appendix B presents a composite of the 23 Plant Evaluation Summaries and denotes the relative ranking of each of the seventy factors examined during the study.

TABLE 1. PRIORITY LISTING OF CAUSES OF LIMITED PERFORMANCE

Ranking	Cause	Total Points	Times Ranked No. 1
1	Operator Application of Concepts and Testing to Process Control	36	4
2	Sludge Wasting and Return	26	3
3	Process Control Testing	24	0
4	Process Controllability	23	1
5	Technical Guidance for Process Control Adjustments	21	0
6	Industrial Loading	20	2
	Sewage Treatment Understanding	20	2
8	O&M Manual Adequacy	20	0
9	Training	18	0
10	Infiltration/Inflow	16	3

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On the basis of the 23 plants evaluated, the most frequent and severe problem was the lack of application of treatment concepts and unit operation testing in controlling the biological portion of the process. This problem was ranked as the most severe deficiency at four of the 23 plants investigated. Although in some cases normal plant operations included regular monitoring of the biological process, the analytical results were often not applied for control purposes. Also, knowledge of basic biological process control theory did not necessarily mean the control theory was practiced. Other priority problems are closely related to this particular factor as will be discussed below.

Design errors or deficiencies with sludge wasting and return systems were found to be the second most frequently occurring problem. This problem primarily involved smaller (< 1 mgd) plants that were not designed with the flexibility for conveying sludge to different points within the plant. For example, many small activated sludge plants were equipped with air lifts instead of conventional sludge pumping facilities. As such, the operator was impeded in his efforts to optimize the biological process, since sludge return rates could not be adequately controlled with that type of conveyance.

Closely related to the first-ranked problem, is the lack of an adequate process control testing program. Standard unit operation control tests, including mixed liquor suspended solids (MLSS), mixed liquor volatile suspended solids (MLVSS), mixed liquor settleable solids, mixed liquor dissolved oxygen, and return sludge suspended solids were conducted at least occasionally by most of the individual activated sludge facilities. The main problem with process monitoring at these plants was that not all necessary tests were performed. For example, while MLSS was monitored, dissolved oxygen monitoring in the aeration zone was frequently ignored. Another problem was that although some plants conducted all the necessary unit operation control tests, the frequency of performance was inadequate, often less than once per week. Although the applicability of process monitoring is not as evident in trickling filter operations, certain areas, such as the effluent from the primary clarification stage and filters, can be observed as a means of gauging unit process performance. At five of the ten trickling filter facilities evaluated under this project, such monitoring was seldom or never performed.

Deficiency in plant design with respect to process controllability was reported to affect plants of all sizes, trickling filter and activated sludge systems alike. Such deficiencies included the inability to vary or monitor return sludge rates, recirculation rates in trickling filters, and air input. Also, the inability to control flow distribution at various points within the plants was reported. Similarly, the use of air lifts greatly reduced the level of controllability at smaller activated sludge facilities. Trickling filter plants inherently do not have the flexibility of the activated sludge systems, but in some cases there was insufficient provision to vary the most basic trickling filter control parameter, recirculation rate. The ability to vary inter-process flows is notably absent in many trickling filter facilities.

The fifth most frequently occurring factor was the absence of suitable technical guidance needed to make effective process control adjustments. No

doubt, this condition is partly responsible for the lack of application of concepts and testing, noted as the highest ranked factor. Examples of such technical guidance include assistance from consulting engineers and other experts andpublications from the U.S. EPA and state regulatory agencies. Although much of the information provided by government agencies is available at little or no cost, few plants had these publications on file, and those that did, rarely referred to them. Furthermore, operators indicated to the field investigators a desire to receive more guidance for process control, but acknowledged that funds were not available from the local government.

Industrial loading was the most significant problem at two of the 23 preliminary evaluation plants, although it was an intermittent problem at several of the facilities evaluated. In most cases where industrial loading was determined to be a problem, these waste streams consisted of excessive levels of pollutants that were compatible with the treatment plant. The problem was not normally one of discharging toxic substances or pollutants inhibitory to the biological treatment process. Most "troublesome" tributary industries were reported to be discharging high concentrations of BOD and suspended solids. Also, these discharges were often reported to be in the form of "slugs" causing excessive fluctuations in flow and loading at the plants.

An inadequate level of understanding of wastewater treatment concepts was cited as the most significant problem of two plants examined under the preliminary evaluation phase. The difference in point totals between this factor (20) and the first-ranked problem (36) suggests that in many cases the operating personnel were somewhat more knowledgeable with respect to the theory of wastewater treatment and the need for process control testing than was revealed through the application of these concepts and test results to process control. The majority of the operators or their supervisors were informed with respect to the basic functions of their respective plants, including the biological segment of each facility, but frequently were not aware of what actually happens in this unit. Apparently having such knowledge does not insure proper application or optimum plant performance.

Inadequacy of (or lack of) a comprehensive O&M manual was reported to be the eighth most significant cause of performance problems. Deficiencies in this area were cited at over half of the plants evaluated. This particular factor was never determined to be the primary cause of performance problems at any given plant. The measurable impact was usually judged to be moderate. The observation made by the field investigators was that a competent staff could overcome deficiencies in its manual by using equipment information supplied by the manufacturer, as-built construction plans and specifications, O&M materials published by EPA and state regulatory agencies, and recognized wastewater treatment technology texts. To some extent the deficiencies of the O&M manuals undoubtedly has contributed to the lack of process control and, consequently, the poor performance of these plants.

The ninth most frequent and severe cause of poor performance was inadequate training. At five of the sites (all of which were less than 4,920 m^3/day in size) the level of training received by the operating personnel was determined to be inadequate. Four of these plants were trickling filter facilities. Inasmuch as the trickling filter process is generally considered less complex than is activated sludge, one might expect a lower level of staff training at these facilities. However, considerable training is still necessary to effectively operate a trickling filter plant, regardless of its size. Evidence of inadequate training was noted at these four facilities. The small size of the five plants may account for this factor since staff training appears to be somewhat proportional to plant size. A lack of training was not reported to be a significant problem at the activated sludge plants. A possible explanation for the overall relative adequacy of training programs at these facilities may be that 16 of the 23 preliminary evaluation plants were located in the state of New York, which has long been recognized for its work on the state level in promoting operator training and certification programs.

Although infiltration/inflow was reported to be the most significant problem at three of the preliminary evaluation plants, only two additional facilities reported any appreciable problem with infiltration/inflow. Generally, the widespread problem of infiltration/inflow encountered during the earlier studies in Region III was not encountered in this project. Two probable reasons for this are differences in climate and topography and better collection system maintenance and repair in the geographical areas included in this study.

A review of the ten priority causes of limited plant performance indicates that deficiencies in process control areas were more critical than design, maintenance, or administrative deficiencies. Although performance was not as severely impacted in this phase as in Phase I, the major causes of problems were again process control oriented. The limited Phase II occurrence of major infiltration/inflow problems resulted in the examination of facilities with problems more of an O&M nature. Three of the top five priority causes, namely the application of concepts and testing to process control, process control testing, and technical guidance for process control adjustments, involved process control. The other two priority causes that were design related - sludge wasting and return capabilities and biological controllability - directly impacted the ability of the operating staff to control unit process operations.

DESIGN

Each preliminary evaluation included the examination of plant design information. Included were the analyses of total plant hydraulic and organic loadings, unit process designs, including sludge treatment processes, and plant flexibility. Since the primary objective of the project was to identify areas in which increased performance efficiency could result through improved operation and maintenance practices, design-limiting factors had to be identified before the potential of improved operation and maintenance programs could be evaluated.

Of the 23 plants investigated under the comprehensive performance evaluation phase, four were found to be hydraulically loaded at 25 percent or more above their design flow. Two of these four plants were intermittently overloaded as a result of infiltration/inflow, while the remaining two facilities were overloaded as a result of excessive discharges from sewered customers. Figure 14 presents a distribution of the 23 treatment plants with respect to their present average daily flow. The majority of the plants surveyed were loaded in such a manner that the annual average daily flow was less than the average design flow, although periodic hydraulic overloading due to infiltration/inflow was frequently reported during wet weather. Within the areas studied, hydraulic overloading is undoubtedly more widespread. However, since such overloading was a reason for rejecting a plant for study under the preliminary evaluation phase, one would not expect the subject facilities as a group to be experiencing conditions of constant hydraulic overload.

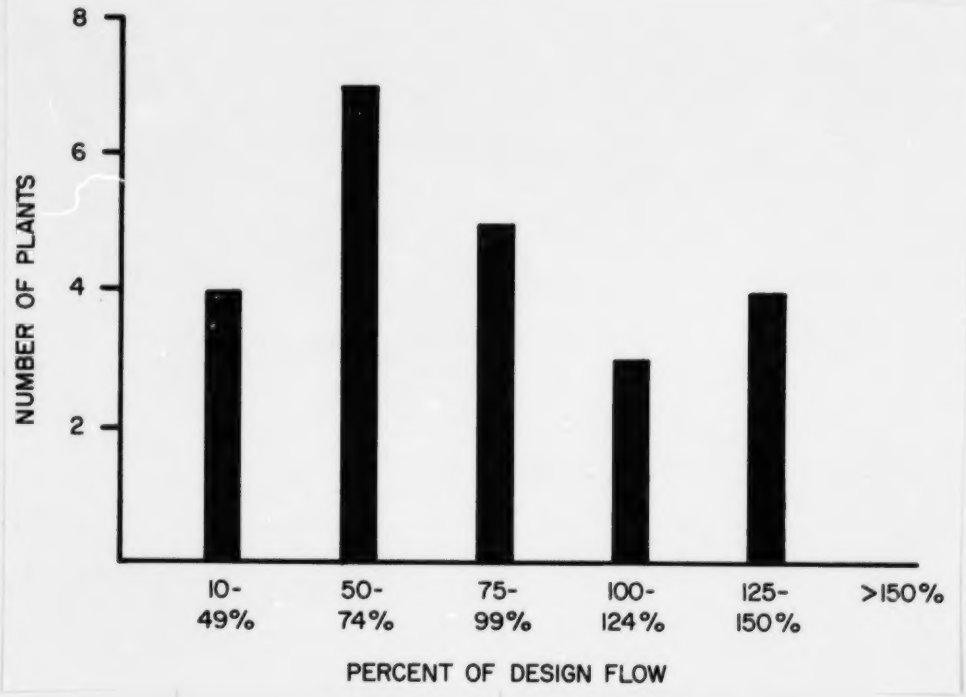

Figure 14. Present Average Daily Flow as a Function of Design Flow

Three of the 23 plants were overloaded 25 percent or more above their design BOD_5 loading. However, two of these facilities were loaded at three times their design organic loading, with adverse impacts on plant performance resulting. In both cases this overload was a result of highly concentrated industrial wastes being discharged into the collection system. Sixteen (75%) of the plants examined under the preliminary evaluation phase were organically loaded at 75% or less of their design BOD_5 loading. Figure 15 presents a distribution of the plants studied under the preliminary evaluation phase with respect to their present annual average BOD_5 loading. As the figure indicates, approximately 70 percent of the plants were loaded at 75 percent or less of their design BOD_5 loading.

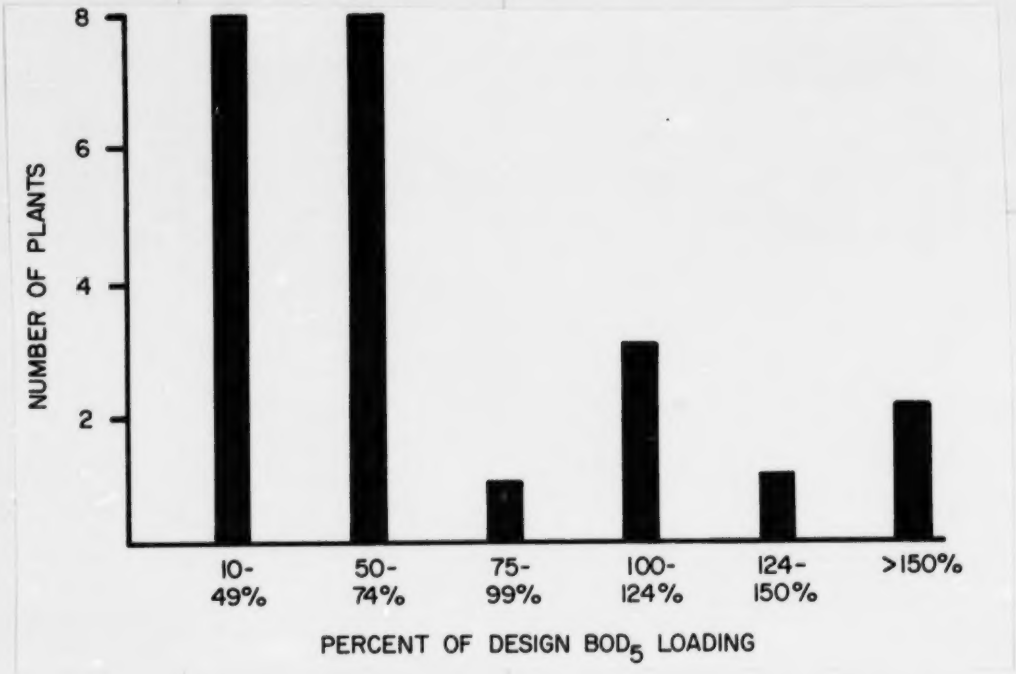

Figure 15. Present Average BOD_5 Loading as a Function of Design BOD Loading

In most cases hydraulic and organic overloads adversely affect plant performance. Specifically, wastewater flows above design parameters result in shortened detention times in settling tanks, aeration tanks, and chlorine contact tanks. As such, key unit process parameters, including clarifier overflow rates and trickling filter hydraulic loading rates, are increased to levels beyond the acceptable range. Organic loadings in excess of design criteria result in high volumetric loadings on both activated sludge and trickling filter systems. Reasonable biomass loadings (F/M) are often difficult to maintain when BOD_5 levels exceed design intent. Also, increased hydraulic and organic loadings are frequently responsible for impaired performance of sludge treatment and handling facilities since sludge production may exceed handling and stabilization capacity.

A comparison of unit process design to actual operating conditions was made on an individual unit basis at each preliminary evaluation site. Design information was obtained from the plant basis of design and drawings when available. These were supplemented by field measurements where necessary. Design adequacy was judged on the basis of experience and recognized published information including: various EPA process design manuals; the "Recommended Standards for Sewage Works - Great Lakes-Upper Mississippi River Board of Sanitary Engineers," commonly referred to as the Ten-States Standards; and wastewater treatment technology texts. Since the design of nearly all existing secondary wastewater treatment plants was subject to the review of the respective state environmental agencies, the unit process design of these facilities would be expected to conform with the design criteria adopted by the individual states, such as the Ten-States Standards. Nevertheless, unit processes at several plants were noted to be improperly designed.

To some extent, performance of eight of the 23 plants evaluated was affected by a lack of duplicate major unit processes. In most cases, these facilities were small trickling filter plants, served by only a single biological unit. The problem is that providing dual trickling filters in such installations may not be economically justifiable, and thus the operators of these facilities are at a disadvantage if the existing single unit must be serviced. At two plants, however, all major unit processes consisted of single units. In such instances, achieving acceptable performance is dependent upon minimizing the period that these units are out of service.

A problem which was noted in the Phase I work concerning the design of the contact-stabilization plants was again seen in this study. Specifically, excessive detention time was provided in the contact aeration stage. Such detention times are specified in various state standards to provide a factor of safety. In practice, the excessive contact times have been shown to result in premature stabilization in the contact zone and, subsequently, a near-endogenous condition in the reaeration zone. As a result, the adsorptive properties of the active biomass in the contact zone are not fully utilized and the biological process does not perform as intended according to theory. In effect, the factor of safety interferes with the biological model on which the contact-stabilization process is based.

Problems with the biological stage were noted at several plants. For example, at plant no. 10, the media in the trickling filter was not of a suitable gradation and, as a result, void spaces were clogged from the sloughing action of the filter. Clogging of the suction line of the return sludge airlift was reported at plant no. 16, with a resultant solids overloading of the secondary clarifier and loss of solids in the plant effluent. At plant no. 48, the on/off cycle of the constant-speed pumps feeding the trickling filters caused the filters to experience hydraulic surges, lessening the contact time between the wastewater and the active biomass.

Several facilities were reported to be experiencing problems with clarification. At plant no. 10, the primary clarifiers provided excessive detention times which resulted in gasification and rising sludge. The design of the sludge hopper in the secondary clarification stage at plant no. 16 caused settling sludge to bridge and, as a result, sludge withdrawal was impeded.

The secondary clarifiers at plant no. 23 were not provided with scum baffles, permitting floating materials to be carried over the weirs. Also, plant no. 62 was served by rectangular secondary settling tanks which, because of improper tank baffling, promoted short circuiting of the wastewater flow.

A design deficiency in the area of disinfection was noted at plant no. 10 in that no chlorine contact tank was provided. Rather, plant design called for disinfection to take place in the plant outfall sewer. However, the two-minute detention time in the outfall did not allow for adequate disinfection.

Numerous design errors and deficiencies in the sludge handling and treatment processes were reported as a result of the preliminary evaluations. Plant no. 01 was supplied with undersized recirculation pumps in the anaerobic digester. At plant no. 24, no provision was made to add diluent water in the sludge thickener as a source of dissolved oxygen to inhibit septic conditions. Plant no. 23 was found to need a sludge thickening stage preceding the existing two-stage digestion process to assist in reducing the pollutant loading in the return stream from the digester. At plant no. 41, an unequal distribution of sludge thickener supernatant to the two biological units at the head of the plant was noted, causing an hydraulic surge and a severe loss of solids in the more heavily loaded unit. Inadequate drying bed capacity and a lack of sufficient sludge disposal sites were noted as design deficiencies at plant no. 56, impeding the operating staff from wasting sufficient volumes of sludge from the biological system. At plant no. 64, an inadequate method of wasting sludge is employed. Sludge from the primary clarification stage cannot be pumped from the tank, but must rely on gravity to be removed and, as a result, accumulates in the clarifier. Also, no sludge thickening or digestion processes are provided at this facility and the existing sludge holding tank is undersized. Plant no. 67 experiences hydraulic overloading of the aerobic digester because of improper elevation of the scum trough in the secondary clarifier.

In summary, the primary purpose of the preliminary evaluation phase was to identify operation and maintenance related problems limiting plant performance and make recommendations for their alleviation. However, routine examination of design parameters showed many plants, previously thought to be adequately designed, had design-related problems. Such design problems, if not corrected, would limit the degree to which improved operation and maintenance programs could upgrade plant performance. Recommendations for corrective operation and maintenance programs must be made within these constraints of design adequacy or accompanied by recommendations for the correction of the design deficiencies.

OPERATION

The third major category of factors affecting plant performance is that of operation, which includes process control adequacy and capabilities, use and adequacy of the plant laboratory, and technical guidance availability. Assessing various aspects of plant operation was based on the experience of the preliminary evaluation field personnel, all of which were engineers or

licensed operators. Factors were rated as adequate, marginal, inadequate, or nonexistent. Evaluation of specific practices or capabilities took into account related factors such as plant size, process type, and permit requirements. In this sense the standards against which operational factors were judged varied among plants. However, the meanings of the four descriptive terms in all cases were the following:

Adequate - practice or capability was not limiting to plant performance, and could not be substantially improved.

Marginal - practice or capability was not normally limiting to plant performance, but could be improved.

Inadequate - practice or capability was insufficient to the extent that it inhibited plant performance.

Nonexistent - no provision existed at the plant for that facet of operation.

Information regarding the laboratories at the preliminary evaluation plants is presented graphically in Figure 16. With respect to performance monitoring, nearly all plants met the monitoring requirements required by state and federal regulatory agency permits. In terms of equipment for conducting both performance and process monitoring, all but two of the 23 preliminary evaluation plants were judged as adequate or marginally adequate. Analytical capabilities were rated nearly as high. As the figure suggests, most plants followed approved sampling procedures and maintained records of laboratory results in a satisfactory fashion.

Because the majority of the preliminary evaluation plants had the capabilities and equipment for performing permit-required testing, these plants were capable of conducting process control testing. However, programs for process control testing were minimal at best. Specifically, although the smaller activated sludge facilities generally maintained a laboratory with the necessary equipment for monitoring mixed liquor suspended solids (MLSS) concentration, mixed liquor dissolved oxygen (D.O.) concentrations, and sludge setteability, these tests were often not performed on a regular basis.

Figure 17 sets forth a summary of the 23 preliminary evaluation plants with respect to process control. As the graph indicates, the personnel at the various plants were shown to have a marginal-to-adequate understanding of the biological process at their facility. Also, the extent to which process control is exercised (i.e., utilizing monitoring results and knowledge of process fundamentals to make operational adjustments) is limited. According to the figure, only five plants were reported to exercise a sufficient level of process control. Overall, interpretation of responses to process control was less than adequate. Recordkeeping of process control procedures was not as complete as in other areas, such as performance monitoring or maintenance.

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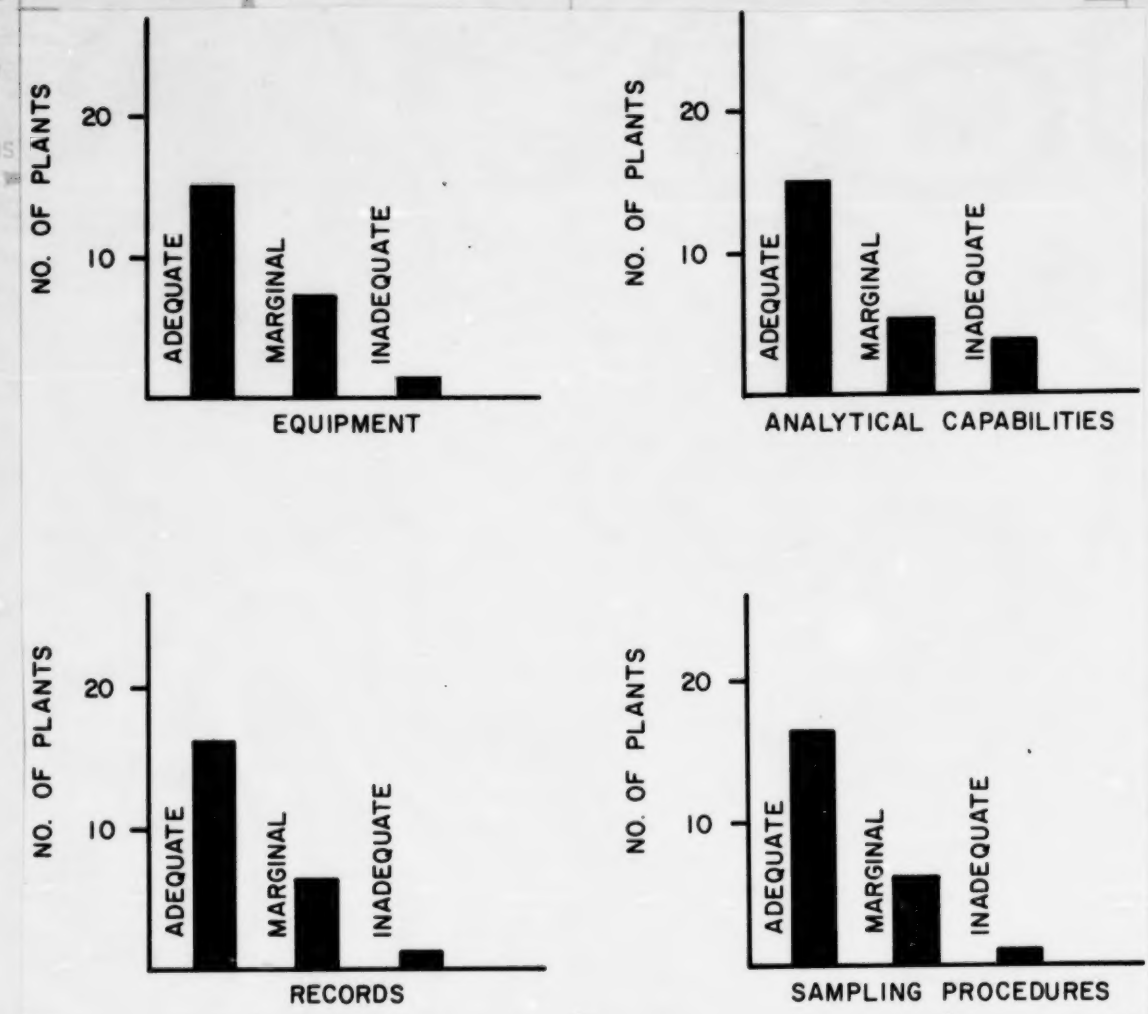

Figure 16. Operation and Maintenance Performance Indicators - Plant Laboratory

In varying degrees of completeness, the plant staffs had several resources available for technical operating assistance, including consultant-prepared O&M manuals, manufacturers' equipment information, and operations assistance from consulting engineers or other experts. Figure 18 presents a graphical summary of various criteria used to evaluate plant O&M manuals, including completeness, clarity with which operating procedures are set forth, information on key equipment (i.e., pumps and aerators), and level of use by plant personnel. Six of the 23 plants evaluated had no O&M manual. References for operation at these six plants consisted solely of information supplied by the manufacturers of major equipment items. Where an O&M manual

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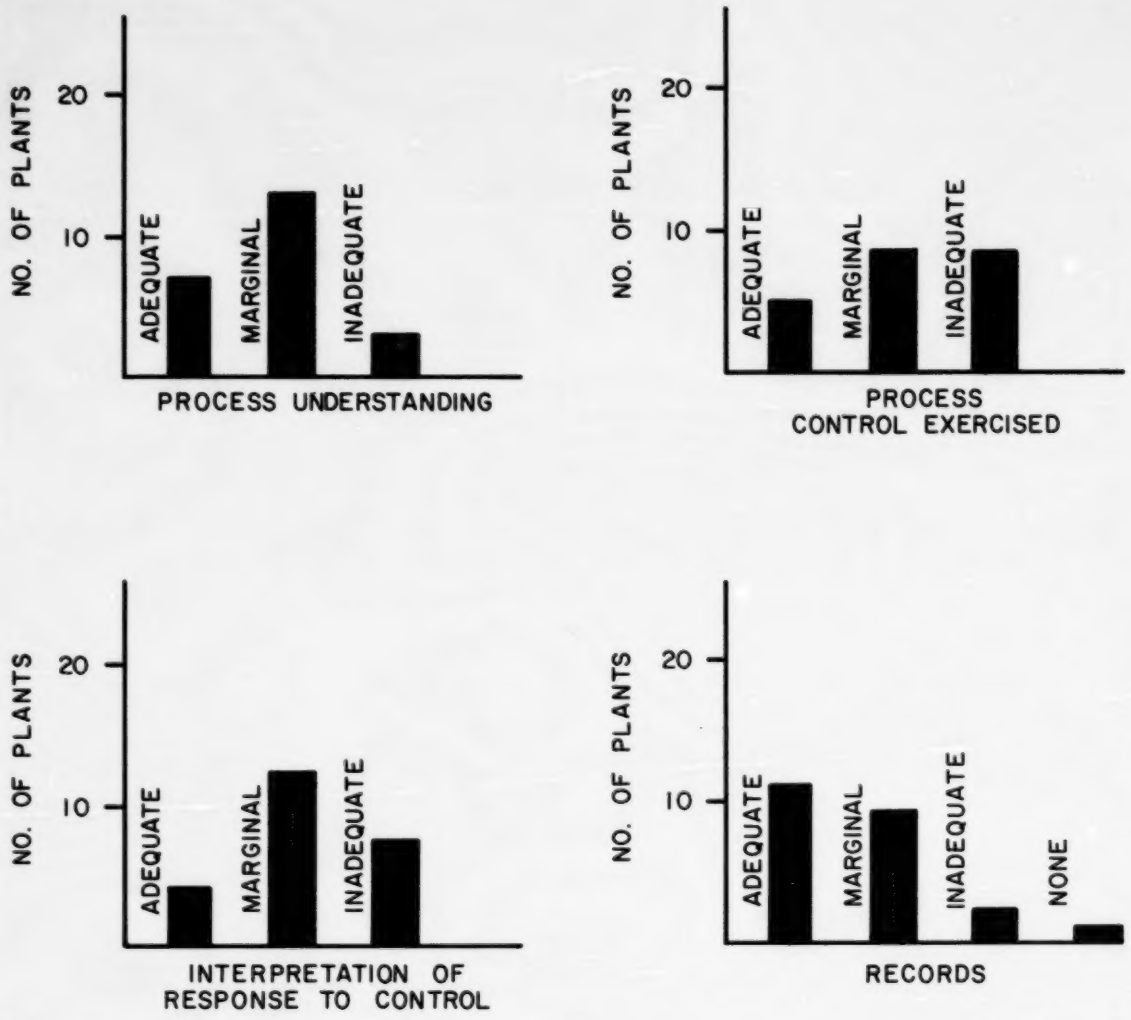

Figure 17. Operation and Maintenance Performance Indicators - Process Control Procedures

had been prepared, specific operating procedures were often addressed only briefly. In only about one-third of the plants evaluated did the O&M manual address the importance of process control parameters and the role of the laboratory in process control procedures. Also, as evidenced by Figure 18, operators rarely made extensive use of the O&M manual and were frequently unfamiliar with its content. At only three plants was satisfactory use of the operating manual observed. For this reason, any training programs aimed at improving plant performance through upgrading O&M practices should, as a principal step, include educating the plant staff in the use of the existing O&M manual.

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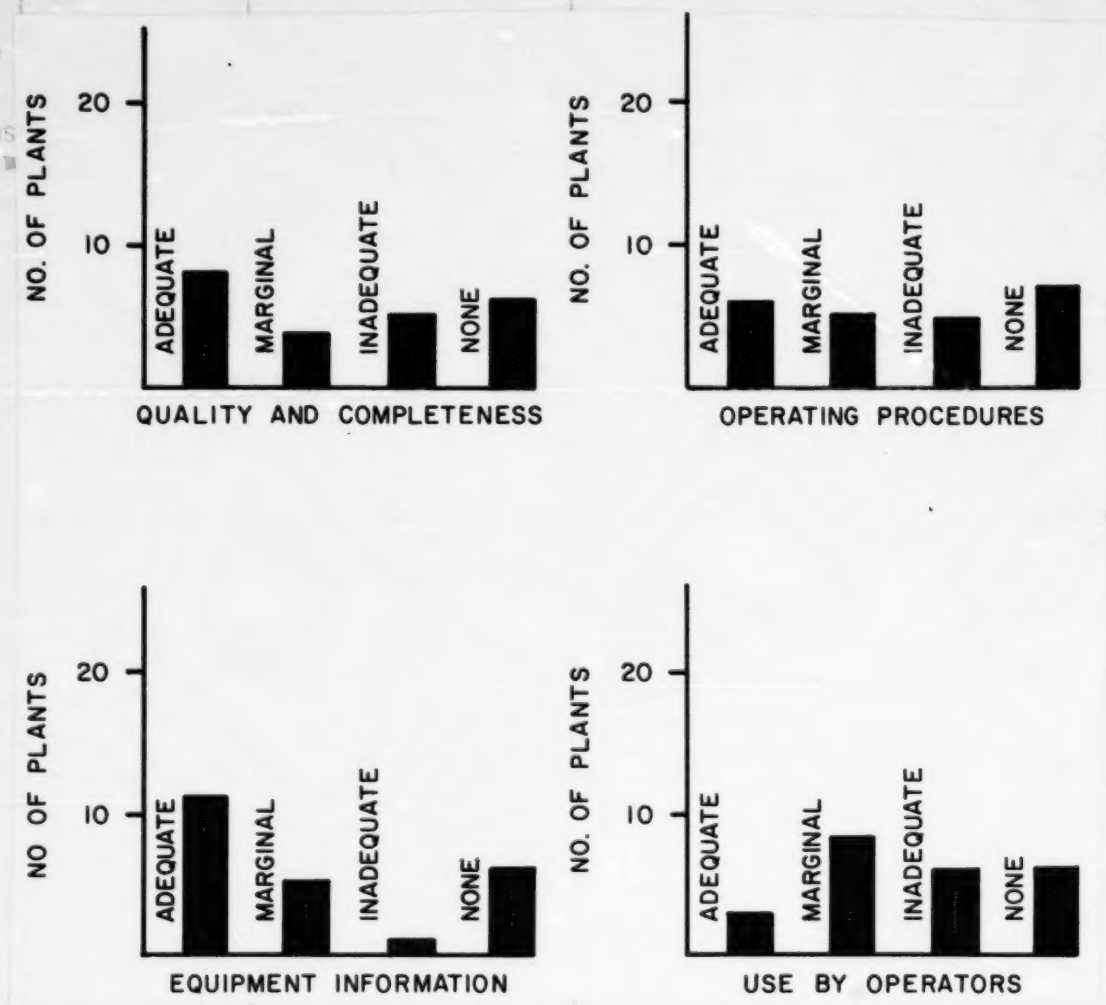

Figure 18. Operation and Maintenance Performance Indicators - Operation and Maintenance Manual

Another source of technical assistance is the operations consultant. Most of the treatment plants studied reported having occasional contact with the design engineer, but had no formal arrangement with a consultant for operations assistance. Operational and process expertise available through consulting engineers and other experts remains a little-used resource at this time.

MAINTENANCE

Maintenance programs and practices were examined at the 23 preliminary evaluation plants from two perspectives - routine and emergency maintenance.

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Figure 19 is a graphical summary of routine maintenance factors. With the exception of maintaining a suitable supply of frequently needed spare parts, a majority of the plants evaluated were rated as adequate in the area of routine maintenance. At only two facilities were performance problems directly attributable to lengthy intervals between maintenance. In both cases, one or more treatment units was reported to be out of service for an extended period. The plants as a group were also relatively reliable in terms of maintaining treatment, as the figure indicates. Overall, housekeeping practices were satisfactory as indicated by the general appearance of the plant grounds and structures. In some cases it was evident that more effort was being devoted to the plant's appearance than to its performance. For the most part, maintaining an adequate inventory of spare parts was not always critical for purposes of sustaining a high level of performance, since most study sites were within relatively short distances of major metropolitan areas in New York, Pennsylvania, and New Jersey and could obtain parts readily. However, delivery times on major parts and components (not normally inventoried at the plant), such as motors, pump, and mixers, was often on the order of months, resulting in reduced treatment efficiency until such components could be replaced.

Emergency maintenance capabilities are summarized for the preliminary evaluation plants in Figure 20. The availability of backup units, as discussed previously, is an important factor in dealing with emergency maintenance situations. Dual or multiple units allow at least partial treatment during equipment failures or periods of scheduled maintenance. During periods of emergency maintenance, parts accessibility and procurement is essential. As the figure indicates, this performance indicator was reported to be only marginal or inadequate at ten of the evaluation facilities. Also, recordskeeping of emergency maintenance was adequate in only slightly more than half of the plants. Only ten facilities were rated as adequate in terms of alarm systems. Such controls include audible and visual alarms for alerting operators to power outages and the failure of major equipment units, such as raw wastewater and sludge pumps, mixers, drive mechanisms on clarifiers and chemical feeders.

ADMINISTRATION

Traditionally, wastewater treatment has been a low priority item for many municipalities. Even in those cases where authorities have been formed to meet the needs of the community, the attitude that properly treating the sanitary wastewaters is not as important as other municipal functions frequently prevails. In many cases local governments and authorities are reluctant to increase taxes or sewer use rentals to offset rising costs of treatment because of the general attitude of the public toward waste treatment. It is somewhat paradoxical that although public opinion has moved toward improving the environment in recent years, the need for improved performance of existing treatment facilities is not often considered in the same context by the public. As a result many treatment facilities are operated with inadequate budgets or staffs. As an average, salaries of wastewater treatment plant personnel are below the level for persons with similar technical responsibilities in private industry. Therefore, the personnel employed generally

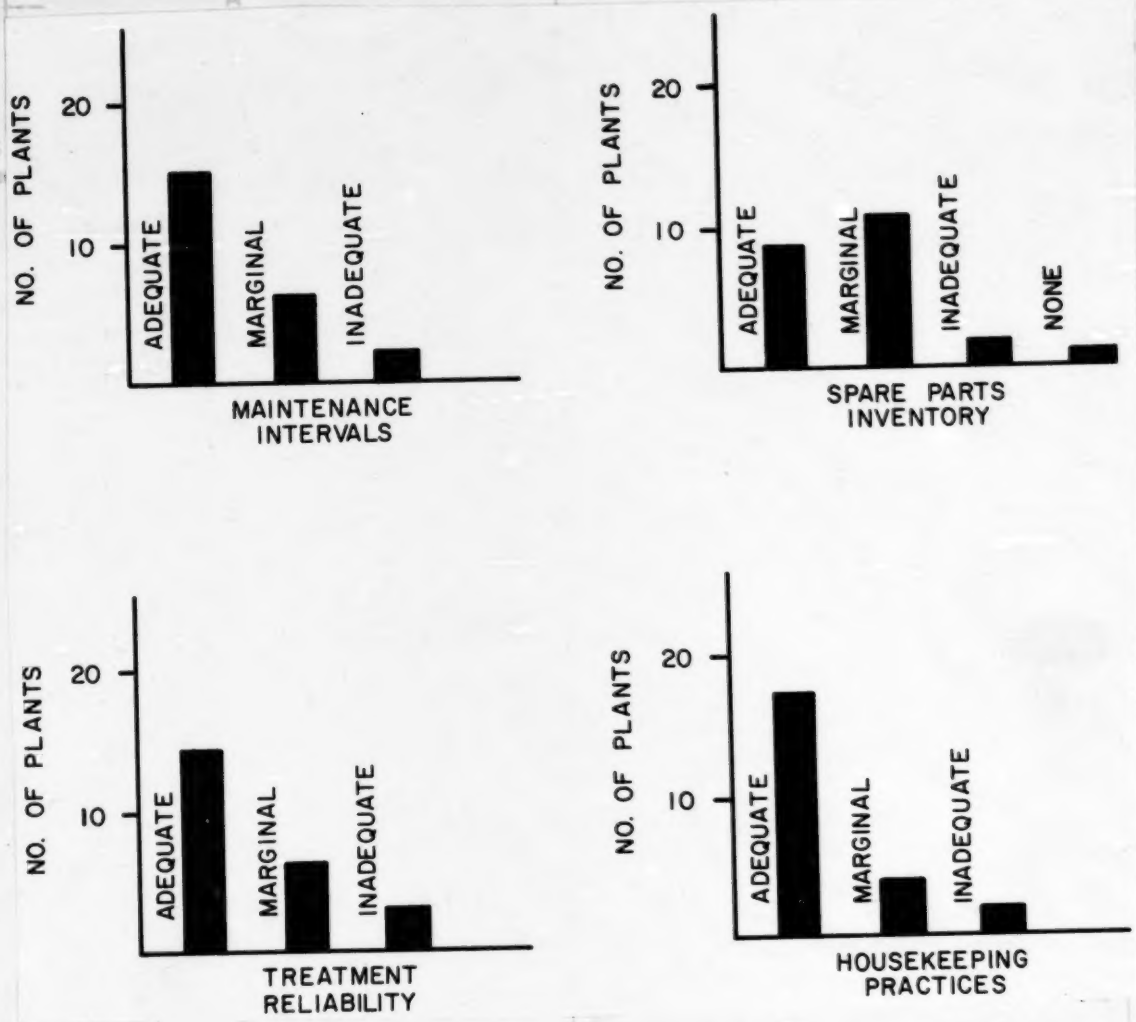

Figure 19. Operation and Maintenance Performance Indicators - Routine Maintenance

require considerable on-the-job training to compensate for a minimal technical background.

Two aspects of wastewater treatment plant administration were examined in detail as part of the preliminary evaluation phase - staffing and budgeting. Published EPA Staffing Guidelines and Budget Surveys were used as a frame of reference for evaluating plant staffs and budgets. While the EPA guidelines were used as a basis for quantifying plant staffing and budget adequacy, the limitations of such methodology must be recognized. The number of operators, for example, does not provide a measure of factors such

as competence or attitude, and these may be significant. Such factors, however, are extremely difficult to quantify.

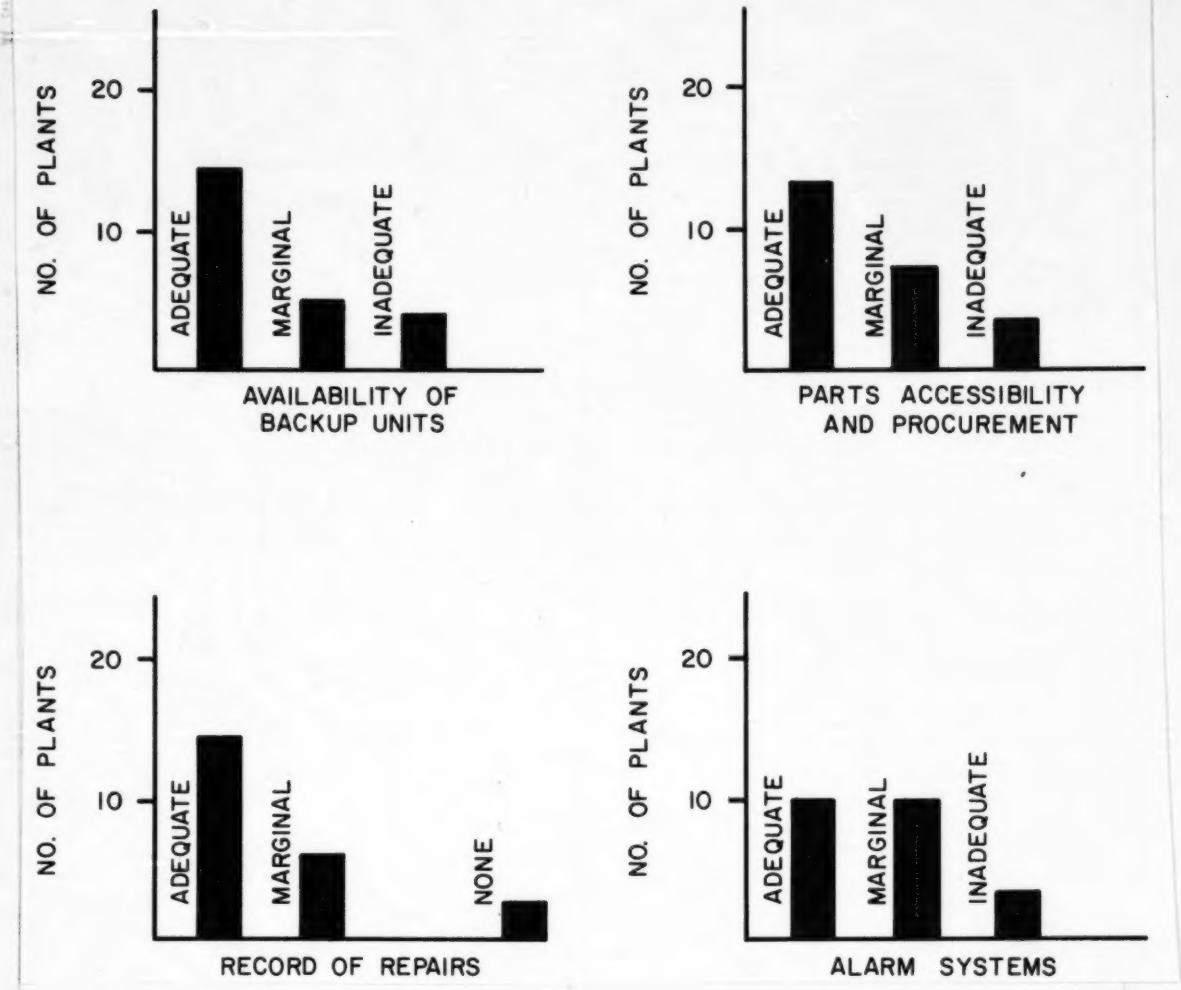

Figure 20. Operation and Maintenance Performance Indicators - Emergency Maintenance

For any wastewater treatment facility to be operated properly, the plant staff must be suitably sized to meet the plant's labor requirements. Plant staffing information, including the manpower levels devoted the major labor categories (supervision, operation, maintenance, and laboratory) was compiled for each of the 23 preliminary evaluation plants. These labor efforts were then compared to the levels recommended by EPA in its technical publication entitled, "Estimating Staffing for Municipal Wastewater Treatment Facilities".

Figure 21 presents a comparison of the actual and recommended staffing levels. As the figure suggests, eight of the preliminary evaluation plants were staffed at a level at least 25 percent less than that recommended. In those cases where performance problems could be traced directly to staffing inadequacies, recommendations were made for increasing the manpower efforts to conform at least with the EPA-recommended levels. It is interesting to note that under the Phase I project, in which 30 plants were evaluated, approximately one-third of those plants were also understaffed to the same extent.

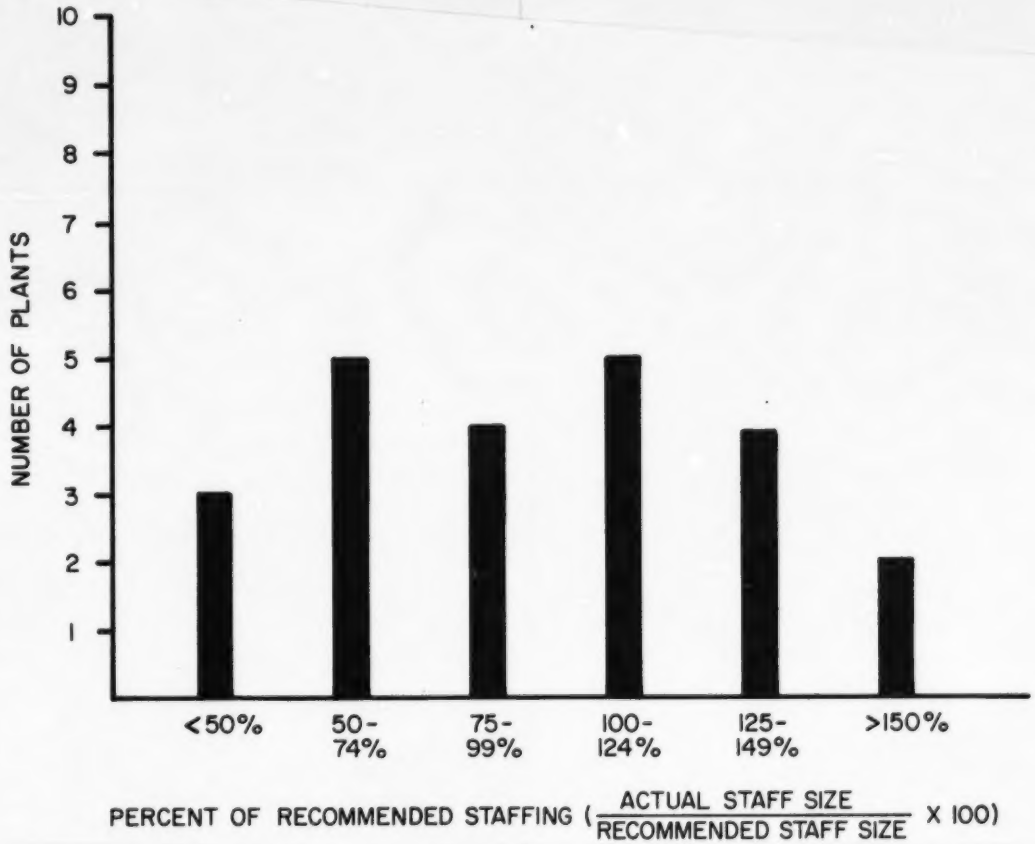

Figure 21. Comparison of Actual Plant Staffing and Recommended Plant Staffing

Budgeting for plant operation and maintenance was examined at each of the preliminary evaluation facilities. Expenditure records or budgets for the year during which our evaluation was conducted were obtained from plant or administrative personnel at each facility. For purposes of comparison, the EPA document, "Analysis of Operation & Maintenance Costs for Municipal Wastewater Treatment Systems," was used. This publication was released in 1978 and was not available in time to be used in many of the preliminary evaluations. However, because the document was published so recently, it represents the most up-to-date information available regarding O&M costs for

treatment facilities. Basically, the report sets forth a summary of O&M costs at numerous treatment plants. Also, the report includes a section which presents O&M costs for plants of various types on a regional basis. Thus, the effects of regional economics are reflected. The O&M costs obtained for the preliminary evaluation plants were compared with the information in the EPA publication. Figure 22 illustrates the results of this comparison. As the figure indicates, a majority of the plants were managed with budgets in excess of the funds expended in operating and maintaining similar plants in the respective geographical area. Inasmuch as this is a comparative analysis of the budgets at these 23 facilities with the actual expenditures at similar installations, it may not reflect the absolute level of funding that is necessary for proper operation and maintenance of a particular facility. However, the findings do indicate that on a relative basis the preliminary evaluation plants were funded at a somewhat greater level than their respective regional averages, and therefore funding should not be a major O&M limitation in this group of plants. However, distribution of funds for various operation or maintenance programs may well be a problem at certain plants.

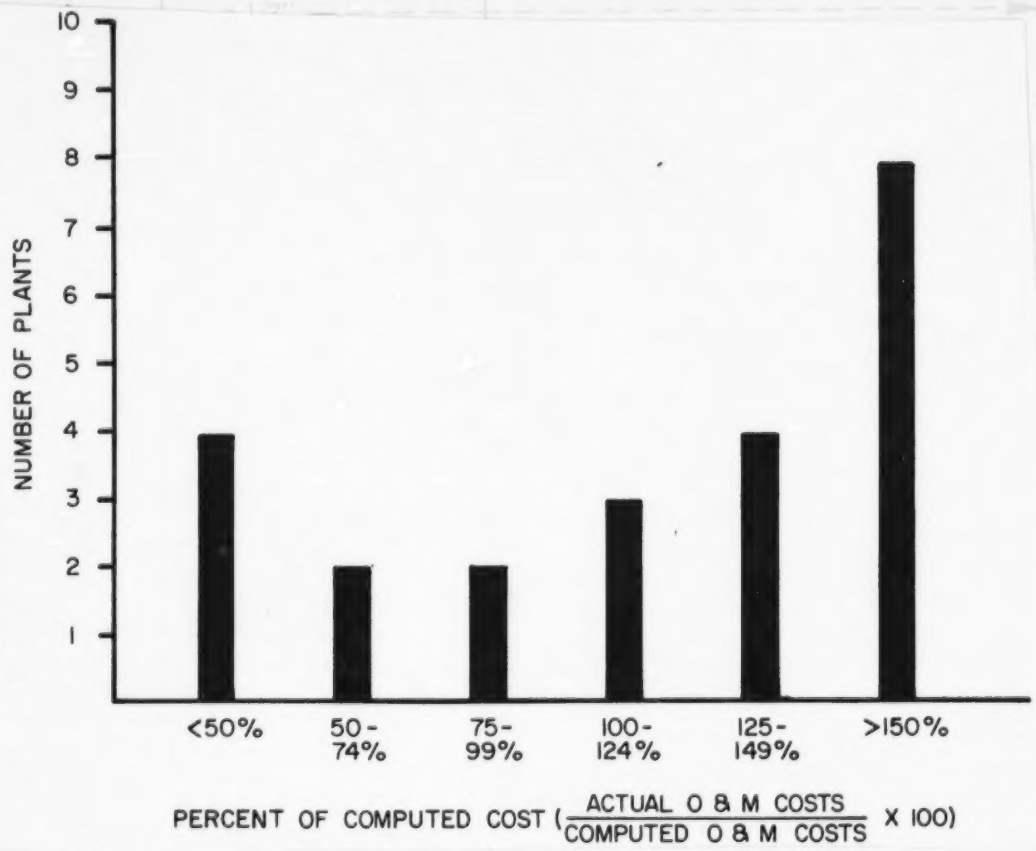

Figure 22. Comparison of Actual O&M Costs with Computed Costs

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SECTION 7

IMPACT OF ESTABLISHED PROGRAMS ON PRIORITY CAUSES OF LIMITED PERFORMANCE

The causative factors of poor plant performance are not of recent origin. Their presence has long been acknowledged, although their priority has been more difficult to identify. Programs have been established by the federal and state governments, operators' associations, manufacturers, and consultants to resolve these problems. The extent of those efforts, and their effectiveness in correcting these problems are discussed in this section.

Since the inception of EPA, the Agency has sponsored the preparation and publication of a number of documents designed to convey state-of-the-art information on wastewater treatment design and operation to those employed in this field. Process design manuals are published by the Government Printing Office and made available through EPA Technology Transfer without fee. These manuals are primarily directed toward those in the consulting engineering and academic fields. Existing volumes address key design areas, such as sludge treatment and disposal, suspended solids removal, upgrading existing treatment plants, and tertiary treatment. These publications set forth specific design parameters for individual unit processes, and are generally intended as a guide for the preliminary design of wastewater treatment facilities. These documents do not contribute to the reduction of operational problems associated with design, and are not directly applicable to the needs of a plant operator.

Operations-related manuals are also available through EPA. Publications such as "Anaerobic Sludge Digestion" and "Stabilization Ponds" outline procedures to be followed in operating and controlling these biological processes. Similarly, the "Procedural Manual for Evaluating the Performance of Wastewater Treatment Plants" includes information, such as a section on common operating problems and suggested solutions, that would be of value to the plant operator. During the site visit phase of the project, it was noted that a number of plants had copies of various EPA publications, primarily the Technology Transfer series. However, it was reported numerous times during the preliminary evaluation phase that these publications normally "gathered dust". The problem appears to be two-fold in that the plant operating personnel are not aware of the extent of usable information contained in the publications, and that the manuals are not written at a level that makes the contents readily comprehendable to the operator.

Under the construction grants program established as a result of the Water Pollution Control Act Amendments of 1972 (PL 92-500) and revised under the Clean Water Act of 1977 (PL 95-217), federal funds are available to

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municipalities seeking to reduce infiltration/inflow. In the design of new facilities involving federal funds, a cost-effectiveness analysis must be performed during the facilities planning step of the project. On the basis of this study, a sewer rehabilitation program may be implemented to reduce infiltration/inflow to the cost-effective level. For plants being enlarged or upgraded, the I/I problem should diminish, but as sewer systems continue to age and deteriorate, new critical cases will develop. The federal program will help to reduce the overall magnitude of the adverse effects of I/I on sewage treatment plant performance when one looks at the overall national picture. However, looking at specific cases, only those plants which become involved in upgrading or expansion will be encouraged to address their I/I situation. Therefore, many plants currently experiencing operational difficulties resulting from excessive I/I will not be affected by existing federal programs.

Established programs to date have had little impact on the industrial loadings to municipal treatment plants. Local programs have consisted of provisions in municipal ordinances setting forth surcharges for discharge of high concentrations of certain pollutants to the collection system, and placing limitations or bans on discharge of other pollutants. However, such ordinance provisions have, in the past been very poorly enforced for two reasons:

1. Time and manpower are not available to vigorously monitor industrial wastes.

2. Rigorous enforcement may have caused conflicts with major employers in the community.

Under PL 92-500, two programs were developed which (while not primarily intended for this purpose) would result in some lessening of the problem of industrial loading. The user charge program requires that all grantees implement a system of recovering treatment plant operation and maintenance costs from its customers in proportion to their wastewater loads and characteristics. Similarly, the industrial cost recovery (ICR) program was established to insure that the recipients of federal grant monies recover (from all industrial dischargers in their service area) the share of the federal capital investment required for treatment of those industrial wastes. Since ICR and user charges are directly proportional to wastewater flows and loadings, the costs to the industry can be substantially reduced by pretreating to reduce pollutant concentrations and by implementing water conservation measures. However, because of concerns expressed by various industries, the EPA is currently reanalyzing the subject of ICR and has placed a moratorium on requiring implementation of the program by grantees pending further study. The ICR provision may well be rescinded, but the user charge system should still provide some incentive to industry to minimize waste discharges, or perhaps pretreat. Municipal treatment plant operations should benefit.

Another regulatory aspect which directly impacts industry are the pretreatment standards, currently being developed by EPA. The regulations promulgated recently identified 21 industrial categories for which specific pretreatment standards have been (or soon will be) developed. Also, "priority

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pollutants" have been designated by EPA. Although these pollutants are highly toxic, at the normally low influent levels found they are not detrimental to the performance of a well operated biological treatment plant and the influent concentrations may be reduced in such facilities. On the other hand, high concentration influent slugs may have an adverse impact on more poorly operated and smaller sized facilities although industrial pretreatment may mitigate the effects.

As part of the construction grants program, O&M manuals are now required for all federally funded wastewater collection and treatment systems. The purpose of this requirement is to insure that all treatment facilities being constructed with federal assistance have comprehensive plant-specific manuals. Through adherence to the EPA document, "Consideration for Preparation of Operation and Maintenance Manuals," and as a result of detailed review by EPA, these manuals should conform to EPA standards. As existing plants are upgraded and new ones built, O&M manual inadequacy should become less of a problem. Also, many consulting firms are now involving the plant operator in the preparation of the O&M manual, and are using the manual as a training device. This should result in a manual that is more responsive to the operators' needs and increased use of the document.

All states now operate a mandatory or voluntary program of operator certification. Though all state programs have been developed and are administered independently, they have had the effect of assuring some minimum competence level for certified operators, usually based on the size and complexity of the treatment plant. In the program's early years, certification was an effective means of increasing the training level of operators. Currently, most plants meet the requirements for certified operators, and enough additional operators are being certified to meet the needs of newly-constructed facilities. Certification programs have their place in assuring minimum competency; however, in their present form, they do not insure that learned principles and techniques will be applied to on-site operational situations.

Training programs play a major part in providing basic wastewater treatment knowledge to potential and practicing treatment plant operators. Examples of such programs include the Sacramento and Clemson courses, and other courses sponsored by the state agencies, water pollution control organizations, technical schools, and community colleges. The availability of training programs will, however, vary from state to state. For example, in Pennsylvania, the Sacramento course is offered through the Department of Community Affairs. This operator training method provides basic understanding of treatment principles and fundamentals, training in laboratory procedures, and exposure to process control technology. Originally, these courses were designed to enable a plant operator to learn the material necessary to become certified. A basic shortcoming of these courses is that they are designed for an individual with little or no wastewater background, and, hence, are limited in what they offer to an experienced individual who seeks to upgrade his skills. In New York, however, the state Department of Environmental Conservation (DEC) takes a more active role in operator training programs. Seminars are sponsored quarterly at a different plant in each of the eight DEC regions in New York. As an incentive for attendance, a portion of the state subsidy for operating costs may be withheld from a municipality if

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its plant operators do not attend these seminars. Also, a relatively detailed publication entitled "Manual of Instruction for Sewage Treatment Plant Operators," prepared by the New York State Department of Health, is available to all operators. Furthermore, EPA's "Operational Control Procedures for the Activated Sludge Process" (more commonly known as the Al West program) has been offered throughout much of New York. Additional training programs are common to most states. For instance, a few community colleges offer advanced courses or an associate degree program, which are designed for experienced individuals interested in supervision of operation and maintenance personnel. Enrollment in these programs requires time and money, which makes them inaccessible to many operators. The courses available to a majority of operators do not provide sufficient depth necessary for meaningful process control application or testing. The findings of this study would indicate that classroom training must be supplemented with on-site training to more effectively convey process control concepts to the operator.

Equipment manufacturers typically provide excellent material on the maintenance and operation of their products, particularly for equipment that is standard or for which operating experience is available. For new products or processes, less information is available, especially in the area of operations. The quality of available assistance in the form of trained personnel varies among manufacturers and among individuals representing each manufacturer. Manufacturers' representatives are a potentially excellent source of knowledge, if suitable contractual arrangements can be made for their services. For small package plants, operators may possibly have access to the manufacturer who could provide operating assistance. For large treatment systems, assistance with the biological process operation is not likely to come from an equipment manufacturer, the possible exception being during start up. However, manufacturers of proprietary unit processes (such as high-purity oxygen activated sludge) can usually provide operating assistance. In general, the manufacturer must be considered as a specialized temporary source of technical assistance to the operator.

Some consulting firms maintain a qualified staff to provide technical and administrative assistance to municipal wastewater clients. Typically included are personnel who are certified treatment plant operators with a thorough knowledge of process theory and design concepts. An engineer without first-hand operating experience is rarely as successful in providing operational assistance as is an experienced operator. Plants evaluated in this study as a group reported a low level of consultant service of this type. Those not retaining consultants felt that consultant services would not be beneficial. Most consulting firms at this time do not maintain the type of staff necessary to offer technical assistance at the operating level, and rarely do they indicate to their clients that such services are available elsewhere. This area of service is expanding, however, and will be offered by an increasing number of specialized consultants in the future.

Within the wastewater industry, associations have existed for a number of years to foster professionalism, increase the technical knowledge of their members, and to effectively represent the members' interest and opinions. Some associations, such as the Water Pollution Control Federation (WPCF), have developed or sponsored operator training courses. Additionally, they

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sponsored conferences, seminars, and workshops, and issue publications aimed at improving the knowledge of plant operators. Such conferences provide the opportunity for operators to discuss problems with their colleagues and occasionally find solutions. The operator's associations provide some valuable training, but as of this time they have had a small to moderate effect on reducing the magnitude of problems associated with process control and understanding.

The problems of application of concepts, lack of adequate testing, improper training, and deficient understanding will not be fully resolved by any of the established programs discussed above. To date, the programs directed at these problems - O&M manual preparation, operator training courses, technology transfer publications, and testing for certification - are too generalized in content while the need is for specific on-site learning experience.

O&M manuals are all too often prepared by the consultant with little or no input from the plant operators. Little opportunity is given the operator to come to an understanding of the manual's contents or to be instructed on how the document should be used. As a result, many O&M manuals are ending up on the shelf, unused. The organizational format of many O&M manuals has been criticized to the EPA in earlier comments by many groups. The accuracy of some O&M manuals is also questionable, since they represent information compiled during the early design stages of a project and do not accurately reflect actual operation.

Operator training courses of all types - Sacramento, Clemson, correspondence, regulatory agency-sponsored, seminars, and workshops - do offer excellent opportunities for textbook learning that can improve an operator's understanding of treatment goals and methods. But very few programs bridge the gap between classroom learning and concept application with hands-on experience or site-specific, on-the-job training. This same difficulty is present in technology transfer publications, and in certification programs that rely solely on (or include as a criterion) the ability to score satisfactorily on a written exam.

Wastewater treatment plants vary in size and complexity and in the quality of the operating personnel. It can safely be said that, in terms of total number of plants, relatively few are both large and complex; the majority are much smaller but may involve some complex processes. Large plants with appropriate budgets can attract qualified superintendents who can insure that lower level personnel are properly trained for their work through both classroom and on-the-job instruction. Smaller plants are less likely to have highly trained superintendents, adequate budgets, and training capabilities, and therefore, are more dependent on training achieved through programs such as certification and government-sponsored courses.

Effective training to produce qualified (not merely certified) operators requires a bridge between the existing training programs and site-specific training assistance in process control and laboratory testing in the plant. The bridging mechanism suggested is best provided by persons who are knowledgeable and experienced in process theory, hands-on operation of equipment

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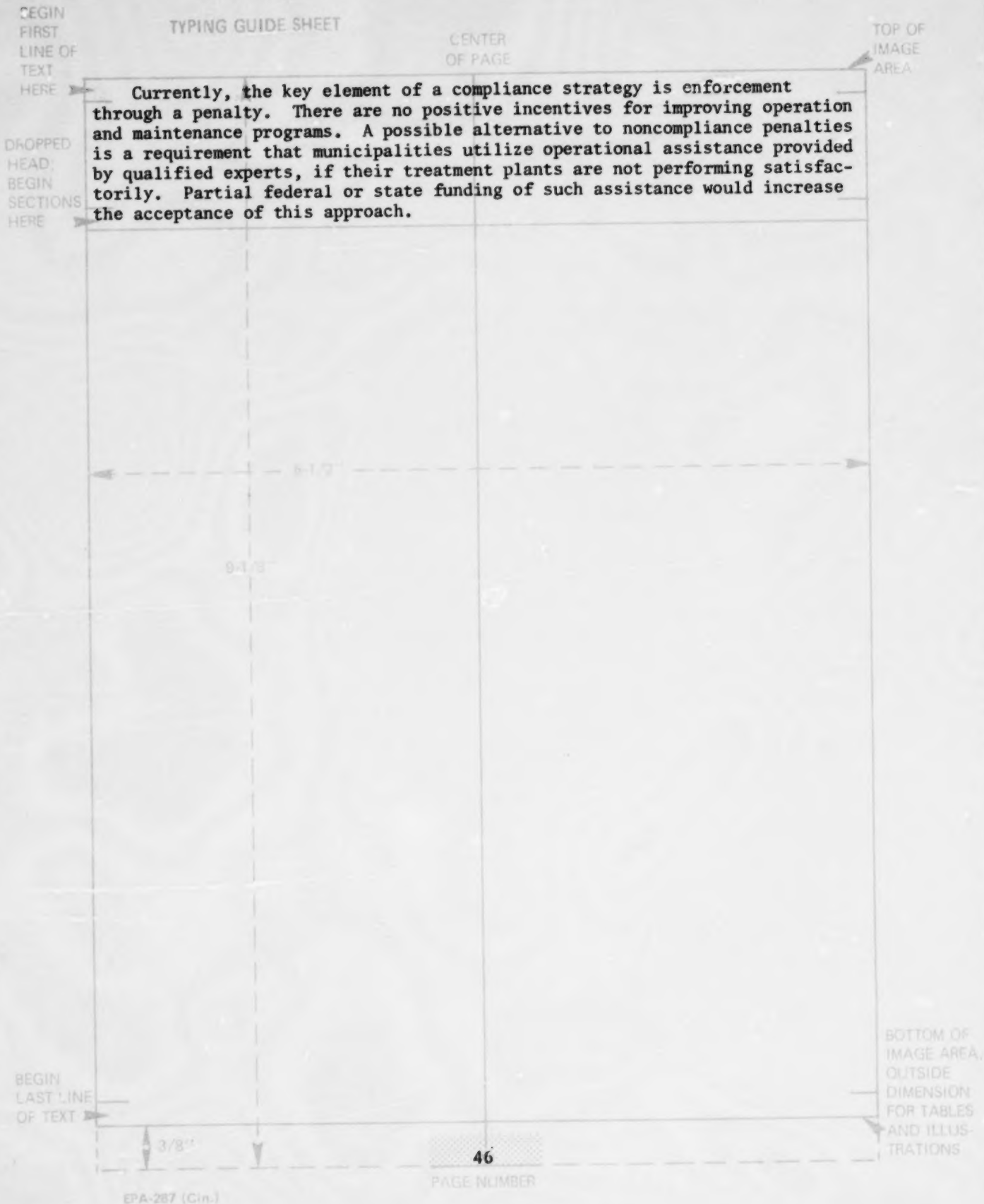
and processes, and training techniques. These persons, working with the plant operators over an extended time period, would be "outside experts" who could both identify and solve problems, and teach the operators process control. In this manner, the operator supplements the knowledge he has gained away from the plant, and is given the opportunity to exercise process control while under the supervision of an experienced individual.

The EPA recognized the viability of such a concept by issuing under the construction grants program its Program Requirements Memorandum (PRM) #77-2 in November 1976. This PRM authorized grant funding for up to 300 man-days (an average of 90 man-days for most plants) of start-up services per plant for the plant's first year of operation, to be rendered by the design engineer or his designees. These covered services, applicable to new, expanded, or upgraded plants, include pre and post start-up on-site training, control adjustments to optimize process performance, instruction in laboratory procedures, maintenance and records management, and O&M manual revision. Specifically non-grant fundable are routine, entry-level, or update operator training.

PRM #77-2 was established to fund start-up services to insure that: "design operational efficiency is achieved as quickly as possible; process control and related equipment problems are identified and resolved; on-site instruction to personnel in details of the process and equipment of each particular plant is provided, and final revisions to the O&M manual, based upon actual operating experience, are made." Plants which have recently upgraded or do not need to construct additional processes to handle their design loadings will not be eligible for this assistance. Yet, as this study has shown, plants in this category may also be experiencing severe problems preventing their achieving permit compliance. The type of service detailed in PRM #77-2 should be available to all plants requiring assistance in problem-solving regardless of the age of the facility. Although they are not eligible for federal funding, these services are available to a varying degree from consulting firms but are seldom used. Making such services eligible for federal funds would increase the likelihood that municipalities would use them. Under the existing statutes, EPA or the states cannot require a municipality to use such services.

Recent modifications to the construction grants program, as set forth in The Clean Water Act of 1977 (PL 95-217) provide for increased federal assistance in waste treatment projects involving innovative technology. The subject of innovative technology may be thought of as a two-sided coin. On one side is the improved level of performance, achievable with the innovative process; whether the process is capable of a higher degree of treatment than previously used systems or is more conservative in terms of energy or raw materials. On the other side, however, are the problems introduced by utilizing a process, which to this time has received little recognititon. Operators may be totally unfamiliar with operating techniques associated with a technologically innovative process. For this reason, additional efforts will be required for instructing the individuals responsible for the operation of these systems, since their experience would typically be limited to the more conventional processes or, at best, a general knowledge of the innovative system's concept.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Currently, the key element of a compliance strategy is enforcement through a penalty. There are no positive incentives for improving operation and maintenance programs. A possible alternative to noncompliance penalties is a requirement that municipalities utilize operational assistance provided by qualified experts, if their treatment plants are not performing satisfactorily. Partial federal or state funding of such assistance would increase the acceptance of this approach.
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EPA-287 (Cin.) (4-76)

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SECTION 8

POTENTIAL FOR IMPROVED PLANT PERFORMANCE

During the preliminary evaluation phase of the project, performance data were compiled from the available plant operating records. These data were statistically analyzed to establish the performance level of each plant. The principal parameters for measuring plant performance were effluent BOD and suspended solids concentrations. Only one of the 23 plants evaluated under the preliminary evaluation phase did not regularly monitor these two parameters and therefore did not have the historical data required for our analysis. Performance data for a 12-month period were analyzed in terms of 30-day average concentrations and compared with the limitations set forth in the plant's NPDES permit. The number of times that the 30-day average BOD and suspended solids concentrations exceeded the permit requirements was determined. Table 2 shows a distribution of the study plants with respect to the frequency of non-compliance with the 30-day average permit limitations. As the table indicates, the 30-day average effluent BOD concentration exceeded the permit requirement at nine plants more than 60 percent of the time. Compliance with suspended solids limits was a little better. Four plants were reported to exceed their 30-day average limitation 60 percent of the time or more. Only 5 (23%) plants were in compliance with both BOD_5 and suspended solids limits 80% of the time or more.

Table 3 presents a summary of effluent characteristics for 22 of the plants studied in the preliminary evaluation phase. The table summarizes the flow, and effluent BOD_5 and suspended solids data reported by the plants for the year preceding the survey. Inasmuch as the BOD_5 and suspended solid tests were frequently conducted improperly or with poor technique by the plant personnel, the reliability and/or representativeness of these data is questionable. Although composite sampling was normally a provision of the NPDES permit of each facility, compositing was not always conducted. Improper sampling techniques were occasionally noted by study personnel with respect to BOD_5 examinations. In addition, the analytical methods employed were often not those approved by EPA. For these reasons, the information in Table 3 may not accurately reflect actual conditions, but the table is based on the best data available for each plant. The data suggest that the facilities examined during the preliminary evaluation phase in the aggregate were discharging average daily BOD_5 and suspended solids loads of 8,532 Kg/d (18,773 lb/d) and 8,233 Kg/d (18,112 lb/d), respectively. Table 4 sets forth the allowable effluent BOD_5 and suspended solids loads based on the present average annual flow and NPDES permit limitations. As the table indicates, at the present average flow an aggregate total BOD_5 and suspended solids load of 7,511 Kg/d (16,523 lb/d) and 7,670 Kg/d (16,872 lb/d), respectively, could be discharged by the plants while still remaining within

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TABLE 2. DISTRIBUTION OF PLANTS WITH RESPECT TO NONCOMPLIANCE WITH NPDES PERMIT STANDARDS

PERCENTAGE OF NONCOMPLIANCE OF PERFORMANCE TESTS WITH 30-DAY AVERAGE LIMITATIONS

Plant No.	BOD_5 60%	BOD_5 40-60%	BOD_5 20-40%	BOD_5 0-20%	Suspended Solids 60%	Suspended Solids 40-60%	Suspended Solids 20-40%	Suspended Solids 0-20%
01				X		X		
02	X						X	
09			X		X			
10	X							X
14	X					X		
15				X				X
16		X					X	
19	X							X
23			X		X			
24		X						X
27	X				X			
28				X				X
33				X				X
39	X				X			
41				X				X
48	X							X
56				X			X	
59				X		X		
61	X					X		
62				X				X
64			X					X
65	X							X
67		N/A				N/A		
TOTAL	9	2	3	8	4	4	3	11

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TABLE 3. CURRENT ANNUAL EFFLUENT CHARACTERISTICS OF PRELIMINARY EVALUATION PLANTS

Plant No.	Average Flow (m^3/d)	Average Flow (mgd)	Average BOD_5 Conc. (mg/l)	Average BOD_5 Load. (Kg/day)	Average BOD_5 Load. (lb./day)	Average S. S. Conc. (mg/l)	Average S. S. Load. (Kg/day)	Average S. S. Load. (lb./day)	NPDES Permit Compliance BOD S.S.
01	795	0.21	30	24	53	30	24	53	YES YES
02	1,250	0.33	18	23	50	19	24	52	NO YES
09	75,700	20.00	26	1,970	4,336	46	3,488	7,673	YES NO
10	4,958	1.31	203	1,008	2,218	26	129	284	NO YES
14	21,590	5.70	45	972	2,139	74	1,599	3,518	NO YES
15	485	0.13	3	1	3	5	2	5	YES YES
16	1,712	0.45	23	39	86	44	75	165	YES NO
19	5,564	1.47	41	229	503	19	106	233	NO YES
23	2,654	0.70	30	80	175	39	104	228	YES NO
24	733	0.19	39	28	62	22	16	35	NO YES
27	11,862	3.13	63	747	1,645	49	581	1,279	NO NO
28	22,130	5.85	94	2,085	4,586	44	976	2,147	YES YES
33	10,310	2.72	21	216	476	18	185	408	YES YES
39	2,037	0.54	151	309	680	78	160	351	NO NO
41	1,156	0.31	5	6	13	12	14	31	YES YES
48	6,094	1.61	37	226	497	23	140	309	NO YES
56	851	0.22	14	12	26	30	25	55	YES YES
59	2,313	0.61	29	67	148	88	204	448	YES NO
61	3,785	1.00	44	167	367	33	125	275	NO NO
62	765	0.20	4	3	7	4	3	7	YES YES
64	3,191	0.84	21	67	147	11	35	77	YES YES
65	7,400	1.96	34	253	556	23	171	376	NO YES
67[1]	568	0.15	-	-	-	-	-	-	- -
TOTAL	187,280	49.48	45.5	8,532	18,773	43.9	8,233	18,112	

[1]Not included in totals

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the 30-day average permit limitations.

As noted previously in this report, specific recommendations were set forth in each of the 23 reports that were prepared following each preliminary evaluation. These recommendations addressed plant operation, maintenance, and administrative program modifications that, if implemented, could result in improved performance of the facility. In most cases it was felt that if the recommendations were carried out, the plants would achieve their optimal degree of performance, beyond which further improvement would not be feasible without physically modifying the existing facilities. Table 5 sets forth estimates of effluent quality for each plant attainable through the implementation of all administrative, operational and maintenance-related modifications, presented in each of the preliminary evaluations. These estimates of attainable effluent quality were developed using engineering judgement on the basis of knowledge of the systems evaluated and of accepted performance standards for properly designed systems. In those cases in which implementation of the recommended operational modifications could result in an effluent quality exceeding that required by the NPDES permit, the permit limits have been used as the attainable effluent quality. Since no real incentive exists to produce an effluent of better-than-required quality, this assumption should realistically represent achievable performance improvements. As shown in the table, total effluent BOD_5 and suspended solids loadings for the combined 22 plants could be reduced to 6,904 Kg/d (15,192 lb/d) and 7,143 Kg/d (15,718 lb/d), respectively, thereby reducing the present average effluent BOD_5 and suspended solids loads to the environment by 1,628 Kg/d (3,581 lb/d) and 1,090 Kg/d (2,394 lb/d), respectively.

On the basis of information compiled during the preliminary evaluation phase, only 12 of the 23 plants examined were producing an effluent which, on an annual average basis, was capable of meeting the 30-day average BOD_5 limitation established in the NPDES permit. Similarly, when analyzed on the same basis, only 15 plants were complying with the suspended solids limit. On the basis of individual monthly averages permit BOD_5 and suspended solids levels were being met 80% of the time or better at 36% and 50% of the plants respectively. In terms of improving performance, it is estimated that 19 of the preliminary evaluation plants would be capable of continuously meeting their respective BOD_5 limitations by implementing the recommendations set forth under each evaluation. Twenty-One plants would be capable of continuously achieving their suspended solids limits. Table 6 summarizes the potential for improved performance at the facilities studied under the preliminary evaluation phase.

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TABLE 4 . DISCHARGE POLLUTANT LOADS BASED ON NPDES PERMIT LEVELS AND PRESENT AVERAGE ANNUAL FLOW

Plant No.	Average Annual Flow (m^3d)	Average Annual Flow (mgd)	Permitted BOD_5 Conc. (mg/1)	Permitted BOD_5 Loading (Kg./day)	Permitted BOD_5 Loading (lb./day)	Permitted S. S. Conc. (mg/1)	Permitted S. S. Loading (Kg/day)	Permitted S. S. Loading (lb./day)
01	795	0.21	40	32	70	40	32	70
02	1,250	0.33	10.4	13	29	30	38	83
09	75,700	20.00	30	2,275	5,004	30	2,275	5,004
10	4,958	1.31	100	497	1,093	60	298	656
14	21,590	5.70	30	648	1,426	70	1,513	3,328
15	485	0.13	5	2	5	30	15	33
16	1,712	0.45	30	51	113	40	68	150
19		1.47	30	167	368	30	167	368
23	2,654	0.70	30	80	175	30	80	175
24	733	0.19	30	22	48	30	22	48
27	11,862	3.13	30	356	783	30	356	783
28	22,130	5.85	100	2,218	4,879	70	1,552	3,415
33	10,310	2.72	30	310	681	30	310	681
39	2,037	0.54	30	61	135	30	61	135
41	1,156	0.31	30	35	78	30	35	78
48	6,094	1.61	30	183	403	30	183	403
56	851	0.22	30	25	55	30	25	55
59	2,313	0.61	35	81	178	80	185	407
61	3,785	1.00	30	114	250	30	114	250
62	765	0.20	30	23	50	30	23	50
64	3,191	0.84	30	95	210	30	95	210
65	7,400	1.96	30	223	490	30	223	490
67[1]	568	0.15	30	17	38	30	17	38
TOTAL	187,280	49.48	40.0	7,511	16,523	40.9	7,670	16,872

[1]Not included in totals

TABLE 5. EFFLUENT CHARACTERISTICS ATTAINABLE THROUGH IMPLEMENTATION OF RECOMMENDATIONS

Plant No.	Average Annual Flow (m^3/d)	Average Annual Flow (mgd)	BOD_5 Conc. (mg/l)	BOD_5 Load. (Kg/day)	BOD_5 Load. (lb./day)	S. S. Conc. (mg/l)	S. S. Load. (Kg/day)	S. S. Load. (lb./day)	NPDES Permit Compliance BOD	NPDES Permit Compliance S. S.
01	795	0.21	30	24	53	30	24	53	YES	YES
02	1,250	0.33	18	23	50	19	24	52	NO	YES
09	75,700	20.00	26	1,970	4,336	40	3,033	6,672	YES	NO
10	4,958	1.31	100	497	1,093	26	129	284	YES	YES
14	21,590	5.70	30	648	1,426	70	1,513	3,328	YES	YES
15	485	0.13	3	1	3	5	2	5	YES	YES
16	1,712	0.45	23	39	86	40	68	150	YES	YES
19	5,564	1.47	30	167	368	19	106	233	YES	YES
23	2,654	0.70	30	80	175	30	80	175	YES	YES
24	733	0.19	30	22	48	22	16	35	YES	YES
27	11,862	3.13	30	355	783	30	355	783	NO	YES
28	22,130	5.85	94	2,085	4,586	44	976	2,147	YES	YES
33	10,310	2.72	21	216	476	18	185	408	YES	YES
39	2,037	0.54	50	102	225	30	61	135	NO	YES
41	1,156	0.31	5	6	13	12	14	31	YES	YES
48	6,094	1.61	30	183	403	23	140	309	YES	YES
56	851	0.22	14	12	26	30	25	55	YES	YES
59	2,313	0.61	29	67	148	30	69	153	YES	YES
61	3,785	1.00	30	114	250	30	114	250	YES	YES
62	765	0.20	4	3	7	4	3	7	YES	YES
64	3,191	0.84	21	67	147	11	35	77	YES	YES
65	7,400	1.96	30	223	490	23	171	376	YES	YES
67[1]	568	0.15	-	-	-	-	-	-	-	-
TOTAL	187,280	49.48	36.8	6,904	15,192	38.1	7,143	15,718		

[1]Not included in totals

TABLE 6 . SUMMARY OF IMPROVED PERFORMANCE

	BOD_5		Suspended Solids	
	(Kg/day)	(lb/day)	(Kg/day)	(lb/day)
Current Annual Average Effluent Characteristics	8,532	18,773	8,233	18,112
NPDES Permit Levels Based on Present Flow Conditions	7,511	16,523	7,670	16,872
Effluent Characteristics Attainable Through Implementation of Recommendations	6,904	15,192	7,143	15,718
Reduction in Pollutant Loading Through Implementation of Recommendations	1,628	3,581	1,090	2,394
Percentage Reduction in Pollutant Loading Through Implementation of Recommendations	19%		13%	
Percentage of Plants Currently Complying with NPDES Permit Limits $\geq$ 80% of the time	36%		50%	
Anticipated Compliance Based on Implementation of Recommendations	86%		95%	

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SECTION 9

COST OF IMPLEMENTATION OF PROGRAMS FOR IMPROVED PLANT PERFORMANCE

A major objective of this study has been to determine whether appreciable improvement in the performance of municipal biological treatment plants can be obtained through optimization of operation, maintenance, and administrative practices, without making significant capital improvements. Undertaking major capital improvement projects often places a financial burden on communities which cannot be supported without major increases in revenue. Based on available data, such costs are not always necessary. Although costs are also involved where optimization of plant management and operation is undertaken, these costs are normally far less than those associated with facility expansions or upgradings and should be considered part of the normal carrying costs of a municipality in protecting the public's investment.

In this section, cost estimates for implementing example recommended programs for improved performance will be presented. The recommendations used for example purposes are those set forth in the preliminary evaluation reports, prepared for three of the facilities investigated. The three plants selected in this section represented situations where it was estimated that improved performance could be achieved through non capital intensive programs. The estimated costs reflect current prices and are based on providing the level of improvement required to meet permit conditions at each of the three plants. In these three examples, a representative cross section of typically suggested program improvements are presented.

Example No. 1 (Plant No. 10)

Plant No. 10 is a 3,785 m^3/day (1.0 mgd) trickling filter facility. During the 12-month period prior to the preliminary evaluation, effluent BOD_5 concentrations averaged 203 mg/1, resulting in violation of permit limitations 60% or more of the time. The recommendations made to improve the performance of the plant included establishment and enforcement of an industrial pretreatment ordinance, expanded process control testing, preparation of a comprehensive O & M manual, and increased staffing. The costs associated with these improvements have been estimated as follows:

1. Establish and Enforce Industrial Pretreatment Ordinance

   Preparation of ordinance (legal and engineering fees, printing, etc.) $ 2,500

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PAGE NUMBER
EPA-282 (Cin.) (4-76)

Administrative enforcement (salaries, inspection costs, legal and engineering fees, laboratory costs, etc.)	$ 3,000*
2. Expansion of Laboratory Functions to Include Process Control Testing	
Equipment	$ 1,500
Labor costs (sampling and analysis)	$ 3,000*
Training	$ 500
3. Preparation of Comprehensive O & M Manual	
Engineering fees (incl. printing)	$30,000
4. Increasing Staff Coverage on Weekends	$ 4,000*
Total Initial-Year Costs	$46,500
Total Costs Recurring Annually	$10,000

Example No. 2 (Plant No. 59)

Plant No. 59 was designed to receive a wastewater flow of 3,028 m^3/day (0.80 mgd). The extended aeration plant was discharging an effluent with a suspended solids concentration of 88 mg/1, during the year preceding the evaluation. As a result, permit limitations were exceeded 50 percent of the time. Recommendations for improving performance included controlling the activated sludge process using the F/M principle, investigation of sludge disposal alternatives, increasing process monitoring, modifying sludge handling practices, and performing maintenance on the aeration tank diffusers and blower air valve. The costs associated with these improvements are estimated as follows:

1. Upgrading Process Control Using F/M Principle	
Training	$ 1,000
2. Investigation of Sludge Disposal Alternatives	
Engineering fees	$ 3,000
3. Expanding Process Monitoring Program	
Labor Costs (sampling and analysis)	$ 2,000*
4. Increase Rate of Supernating from Sludge	
Holding Tank	-

*Cost recurring annually

5.	Clean No. 2 Aeration Tank Diffusers and Repair Blower Air Valve	
	Labor Costs	$ 1,500
	Parts	500
	Total Initial-Year Costs	$ 8,000
	Total Costs Recurring Annually	$ 2,000

Example No. 3 (Plant No. 67)

Plant No. 67 is a 1,514 m^3/day (0.40 mgd) contact-stabilization, package-type facility. Presently, the plant receives only about 50 percent of its design flow. Raw wastewater characteristics appear to be within the normal domestic range. Minimal performance testing is conducted so plant records are inadequate for assessing plant influent or effluent. Unacceptable effluent quality was evident based on visual examination. Excessive non-compliance with discharge permit criteria has been established by the state agency.

Recommendations for improving the performance of the plant included repairing the scum box to eliminate the continuous spill of clarifier supernatant, chemically treating the return sludge to reduce sulfide concentrations and filamentous organism levels, developing the necessary laboratory capabilities for performance monitoring and process control, supplementing the existing operations and maintenance manual, and providing the operator with formal training through locally offered wastewater treatment technology courses. The costs associated with these improvements have been estimated as follows:

1.	Repair Scum Box (parts and labor costs)	$ 200
2.	Develop and conduct chemical addition program for reducing filamentous organism population	
	Chemical costs (using H_2O_2)	$ 2,000*
3.	Develop Laboratory Capabilities for Performance and Process Control Testing	
	Equipment	$ 4,000
	Labor Costs (sampling and analysis)	$ 5,000*
4.	Preparation of Supplement to O & M Manual	
	Engineering fees (including printing)	$15,000
5.	Operator Training	$ 500
	Total Initial-Year Costs	$26,700
	Total Costs Recurring Annually	$ 7,000

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As shown in the three examples presented above, initial-year costs of implementing the three programs ranged from $8,000 to $46,500. Annual costs ranged from $2,000 to $10,000. As indicated, the costs of such improvement programs may be increased dramatically where major deficiencies must be corrected, such as the preparation of an O & M manual or the purchase of laboratory equipment. However, the costs of implementing **any** one of the corrective programs outlined above would be far less than that associated with a physical upgrading of the facility to meet the performance requirements. Furthermore, physical upgrading itself does not guarantee optimum performance. Proper and intelligent operation and management must still be provided. Thus, many recommendations of the composite correction program would necessarily be implemented regardless of any planned physical modifications. From the cost effectiveness standpoint, therefore, the composite correction program is the logical first step in plant performance improvement.

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SECTION 10

COMPARISON OF PROJECT FINDINGS AND CONCLUSIONS

As has been previously noted, this report presents the results of an investigation that was preceded by a similar study (Phase I). The objectives of both studies were to evaluate performance, design, operation, maintenance, and administration of biological treatment plants, and to determine the potential for improved performance through operational and maintenance program modifications, administrative changes, and minor design modifications. Because the two projects were closely similar in scope and objectives, it is logical to compare findings of each. This comparison is made in this section. In addition, the data bases of the two projects have been combined and a list of priority problems representing the 53 plants evaluated under both studies is presented.

In an attempt to obtain data on the effectiveness of operational modifications for improving plant performance, some minor changes in the format for performing the preliminary evaluations were made in Phase II. In the previous project, all on-site investigations were conducted over a three-to-five-consecutive-day period. In this project several one-day return visits were made at intervals of two to four weeks. This extended the preliminary evaluation time span to several months without increasing the total level of effort. In this manner, data collected during an initial visit could be examined, and preliminary recommendations based on that data could be made and, in some cases, implemented. Then, depending on the degree of cooperation afforded by the operator and administrative officials, follow-up data were obtained from the plants showing the impact of implementing these preliminary recommendations relative to effluent quality. However, while the purpose of this slight procedural change was to obtain more data, the major objective of the preliminary evaluation remained the same in this project as it had been in the first study. That objective was to identify and rank problems adversely affecting plant performance.

The significant findings of the Phase II project reported here confirmed the earlier findings. The most frequently encountered problem at the 53 plants examined under both projects was the lack of application of process control. Another related item - process control testing - was a highly ranked cause of performance problems in both projects. The lack of a reasonable understanding of treatment theory was also ranked as one of the ten priority problems under both studies. Whereas inadequate training was determined to be the sixth most frequently encountered cause of performance problems under the first project, a ninth place ranking was assigned in the second project. Other causes; including industrial loading, O&M manual adequacy, and process controllability; were also found to be priority causes of limited plant performance in both projects. However, the problems encountered with

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excessive infiltration/inflow which made it the second most prevalent problem in the previous project, were not as evident during the second project. Table 7 presents a composite listing of the priority problems for the 53 treatment facilities examined under both contracts.

In summary, the conclusions from the two projects are in close agreement. The performance problems encountered at municipal biological treatment facilities are the result of both design and operational deficiencies. Design-related problems are primarily due to excessive organic and hydraulic loadings, caused by industrial discharges and infiltration/inflow. The operator has little or no control over such external factors. However, a significant portion of performance problems are operations oriented, specifically with respect to process control shortcomings. Results of both projects indicate that optimization of plant operations would improve the overall plant performance picture and, as a result, effluent quality from the nation's treatment facilities would also be improved.

TABLE 7. COMPOSITE PLANT EVALUATION SUMMARY (PHASE I AND PHASE II)

Ranking	Cause	Total Points	Times Ranked No. 1
1	Operator Application of Concepts and Testing to Process Control	84	8
2	Infiltration/Inflow	60	7
3	Process Control Testing	60	-
4	O&M Manual Adequacy	54	-
5	Industrial Loading	39	3
6	Process Controllability	38	2
7	Training	36	-
8	Sludge Wasting and Return	35	4
9	Treatment Understanding	35	3
10	Technical Guidance for Process Control Adjustments	35	-

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Appendix A

EPA - PHASE II

SITE VISIT REPORT SUMMARY
GENERAL INFORMATION

Plant No.	Plant Capacity (MGD)	Type of Treatment	Present Service Population	Present Flow (MGD)	Year of Orig. Constr.	Year of Most Recent Upgrading	NPDES Limits (BOD_5/S.S.)	Industrial Wastewater Problems	Infiltration/ Inflow Problems	Supplemental Treatment		
										Preliminary	Primary	Tertiary
01	0.42	TF	2,000	0.21	1972	-	30/30	None	Minimal	GR	PC	-
02	1.0	TF	8,500	0.5	1929	1970	10/30	None	None	GR	PC	-
03	4.0	AS	27,000	2.5	1969	-	30/30	Minimal	Major	GR	PC	-
04	9.3	TF	40,000	10.5	1936	1972	34/275	Minimal	Major (c)	GR	PC	-
05	0.32	AS	1,700	0.3	1967	-	30/30	Minimal	Moderate	-	-	PL (not used)
06	2.5	AS	20,000	3.8	1965	-	35/30	Moderate	Severe	GR	-	-
07	1.0	AS	6,000	0.6	1935	1971	30/30	Major	Minimal	-	PC	-
08	2.0	TF	15,000	1.4	1934	1973	30/30	Minimal	Moderate	GR	PC	-
09	18.25	AS	150,000	17.6	1960	1973	22/24	Major	Unknown	GR	PC	-
10	3.0	TF	5,300	1.5	1966	-	125/100	Major	Major (c)	GR	PC	-
11	2.7	AS	29,500	2.5	1938	1977	25/30	Minimal	Major (c)	GR	PC	-
12	4.0	AS	18,400	3.5	1971	-	30/30	Moderate	Major	GR	-	-
13	0.75	TF	10,000	0.75	1967	-	30/30	None	Minimal	-	PC	PL
14	4.8	TF	26,000	6.5	1963	-	30/70	Major	Major	GR	PC	-
15	0.2	AS	1,400	0.12	1972	-	5/30	Minimal	Minimal	-	-	SF
16	0.75	AS	5,000	0.65	1964	-	30/40	Minimal	None	GR	-	-
17	2.93	AS	15,000	2.2	1956	1973	20/25	Minimal	Moderate	GR	PC	-
18	2.13	TF	15,000	1.5	1970	-	45/40	Moderate	Major	GR	PC	-
19	1.0	TF	2,800	1.5	1972	-	30/30	Moderate	Major	GR	PC	-
20	2.0	TF	11,000	1.6	1935	1957	40/60	Major	Major	GR	PC	CP
21	6.7	TF	45,000	6.5	1966	1973	30/30	Minimal	Major	GR	PC	-
22	0.52	AS	3,000	0.2	1965	1970	30/30	Minimal	Minimal	GR	-	-
23	1.0	AS	8,500	0.74	1966	-	30/30	Minimal	Minimal	GR	PC	-
24	0.3	TF	2,000	0.12	1974	-	30/30	None	Minimal	-	PC	-
25	4.5	AS	-	3.0	1972	-	120/50	Major	Minimal	-	PC	-
26	2.12	TF	11,500	1.5	1952	1975	10/10	Moderate	Major	GR	PC	MS
27	4.0	AS	16,000	2.5	1973	-	30/30	Minimal	Major	-	PC	-
28	4.0	TF	27,000	6.0	1908	1964	100/70	Moderate	Major	GR	PC	-
29	1.5	TF	6,500	1.0	1940	1969	30/50	Major	Major	GR	PC	PL (not used)
30	2.7	TF	16,900	2.8	1967	1977	32/30	Minimal	Moderate	GR	PC	-
31	1.5	TF	11,000	1.0	1934	1967	40/30	Minimal	Minimal	GR	PC	-
32	5.0	AS	50,000	5.0	1956	1972	72/66	Major	Major (c)	GR	PC	-
33	4.0	AS	13,200	3.2	1970	-	30/30	Moderate	Moderate	GR	PC	-
34	8.0	TF	45,000	6.5	1936	1960	35/60	Minimal	Moderate	GR	PC	-
35	4.0	AS	39,000	3.1	1916	1967	30/30	Moderate	Moderate	GR	PC	-

Appendix A

EPA - PHASE II

SITE VISIT REPORT SUMMARY
GENERAL INFORMATION (Continued)

Plant No.	Plant Capacity (MGD)	Type of Treatment	Present Service Population	Present Flow (MGD)	Year of Orig. Constr.	Year of Most Recent Upgrading	NPDES Limits (BOD_5/S.S.)	Industrial Wastewater Problems	Infiltration/ Inflow Problems	Supplemental Treatment		
										Preliminary	Primary	Tertiary
36	2.2	AS	22,000	1.7	1959	1978	30/38	Moderate	Moderate	GR	PC	-
37	3.0	AS	28,000	2.2	1954	1972	20/20	Minimal	Minimal	GR	PC	-
38	1.5	TF	6,900	0.9	1934	1967	30/30	None	Moderate	GR	PC	-
39	0.6	AS	-	0.52	1970	-	30/30	Major	Minimal	-	-	-
40	1.7	TF & AS	6,000	1.64	1967	-	75/75	Moderate	Moderate	-	-	-
41	1.0	AS	5,000	0.4	1954	1972	30/30	None	Minimal	-	-	-
42	1.5	AS	11,000	1.4	1935	1959	30/30	Minimal	Minimal	GR	PC	-
43	1.0	AS	1,600	0.8	1972	-	30/30	None	Minimal	-	-	-
44	3.0	AS	17,300	2.0	1926	1974	10/12	Minimal	Minimal	GR	PC	MS
45	7.0	AS	26,000	5.0	1970	-	85/30	Minimal	Major	GR	PC	-
46	5.0	AS	12,000	1.3	1969	1977	30/30	Major	Major	-	PC	-
47	4.0	AS	19,000	2.5	1967	1971	30/38	Minimal	Minimal	-	PC	-
48	1.2	TF	7,500	2.0	1928	1965	30/30	None	Moderate	GR	PC	-
49	0.5	TF	2,800	0.3	1959	1973	30/30	Moderate	Minimal	GR	PC	-
50	0.8	TF	4,500	0.9	1974	-	15/36	Major	None	-	PC	-
51	3.0	TF	30,000	3.2	1950	1969	30/30	Minimal	Moderate	GR	PC	-
52	8.0	AS	30,000	3.8	1977	-	30/30	Minimal	Minimal	GR	PC	-
53	2.8	AS	12,600	1.6	1944	1972	10/12	Minimal	Moderate	GR	PC	MS
54	1.5	TF & AS	10,500	1.0	Unknown	1972	15/18	Minimal	Moderate	GR (not used)	PC	PL
55	3.5	AS	7,000	1.6	1970	-	15/30	None	Major	GR	PC	-
56	0.6	AS	(winter) (summer) 1,500 - 5,000	0.3	1976	-	30/45	Major	Minimal	GR	-	-
57	1.0	AS	5,200	0.3	1930	1970	25/30	None	Minimal	-	-	-
58	1.0	AS	10,000	0.9	1969	-	30/30	None	Major	GR	-	-
59	0.8	AS	5,000	0.6	1962	1962	-	35/80	None	None	-	-
60	2.2	AS	7,500	1.5	1956	1974	10/12	Minimal	Minimal	GR	PC	MS
61	1.3	TF	8,000	1.0	1973	-	30/30	Minimal	None	-	PC	-
62	0.2	AS	2,000	0.2	1975	-	30/30	None	Minimal	-	-	-
63	1.1	TF	Unknown	0.4	-	-	35/35	None	Major	-	PC	-
64	1.2	TF	5,400	1.4	1970	-	30/30	Minimal	Major	GR	PC	-
65	2.5	TF	8,000	2.2	1938	1964	30/30	Moderate	Moderate	GR	PC	
66	8.9	TF & AS	58,000	4.0	1925	1977	10/12	None	Moderate	GR	PC	
67	0.4	AS	2,800	0.2	1969	-	30/30	Minimal	None	-	-	-
68	1.5	TF	Unknown	1.2	1962	1975	10/10	None	Major	GR	PC	SF

Appendix A

EPA-PHASE II

SITE VISIT REPORT SUMMARY
OPERATIONS

Plant No.	Staff Coverage (Hr./Wk.)[1]	Staff Size	Staff Certification	Staff Training	Use of Consulting Engineer	Laboratory Capabilities	Performance Monitoring	Process Monitoring	Process Control	Laboratory Records	Supplemental References
01	40-60	0	0	1	-	0	0	0	0	0	0
02	40-60	0	0	2	2	2	0	2	2	2	0
03	>100	0	0	1	1	0	0	0	0	0	0
04	>100	0	0	0	1	1	0	1	1	0	0
05	40-60	1	0	1	1	0	0	0	0	1	2
06	>100	0	0	0	1	0	0	0	0	0	0
07	40-60	0	0	0	1	0	0	0	0	0	0
08	60-100	0	0	0	1	0	0	0	0	0	1
09	>100	0	0	0	1	0	0	0	0	0	0
10	40-60	1	0	1	0	0	0	1	0	0	0
11	60-100	0	0	2	1	0	0	1	0	0	0
12	>100	0	0	0	1	0	0	1	1	0	0
13	40-60	0	0	0	0	0	0	0	0	1	0
14	>100	0	0	0	1	0	0	0	0	0	-
15	40-60	0	0	0	1	0	0	0	0	0	0
16	40-60	0	3	0	0	0	0	2	2	0	0
17	>100	0	0	0	1	0	0	0	0	0	-
18	>100	0	1	0	1	0	0	1	1	1	0
19	40-60	0	0	2	1	0	0	0	0	0	0
20	>100	0	0	0	1	0	0	0	0	0	0
21	>100	0	0	0	0	0	0	0	0	0	0
22	40-60	0	0	0	1	0	0	0	0	0	0
23	40-60	0	1	1	0	0	0	0	0	0	0
24	20-40	0	0	2	2	1	1	2	2	0	0
25	40-60	1	0	0	0	0	0	1	1	0	0
26	>100	0	0	0	0	0	0	0	0	0	0
27	40-60	0	1	0	1	0	0	1	1	0	0
28	40-60	0	0	0	1	1	0	1	1	0	1
29	40-60	0	0	1	1	1	0	1	1	0	1
30	60-100	0	0	0	1	0	0	0	0	0	-
31	60-100	0	0	0	0	0	0	0	0	0	-
32	>100	0	1	0	1	0	0	1	1	2	0
33	60-100	1	0	0	1	0	0	0	0	0	0
34	>100	0	0	0	1	0	0	0	0	0	0
35	>100	0	0	0	1	0	0	1	1	0	-

Appendix A

EPA-PHASE II

SITE VISIT REPORT SUMMARY
OPERATIONS (Cont'd)

Plant No.	Staff Coverage (Hr./Wk.)[1]	Staff Size	Staff Certification	Staff Training	Use of Consulting Engineer	Laboratory Capabilities	Performance Monitoring	Process Monitoring	Process Control	Laboratory Records	Supplemental References
36	60-100	1	1	0	1	0	0	0	0	0	0
37	40-60	0	0	0	0	0	0	1	1	0	0
38	>100	0	0	0	1	0	0	0	0	0	-
39	40-60	0	1	0	0	0	0	0	0	0	0
40	40-60	0	0	0	1	0	0	0	0	0	0
41	40-60	1	1	0	0	0	0	1	1	0	0
42	40-60	0	0	1	0	1	0	1	1	0	0
43	40-60	0	1	0	1	0	0	0	0	0	0
44	40-60	0	0	0	1	0	0	1	0	0	0
45	>100	1	0	1	1	0	0	1	1	0	1
46	>100	0	1	1	0	0	0	0	0	0	0
47	>100	0	0	0	1	0	0	0	0	0	0
48	>100	0	0	0	1	0	0	1	1	0	0
49	40-60	0	0	0	1	0	0	0	0	0	0
50	40-60	0	0	0	1	0	0	0	0	0	0
51	40-60	0	0	0	0	0	0	0	0	0	-
52	>100	0	1	0	1	0	0	0	0	0	0
53	>100	0	0	0	1	0	0	0	0	0	-
54	40-60	0	0	0	1	2	2	1	0	0	0
55	40-60	0	0	0	1	0	0	0	0	0	0
56	40-60	0	0	0	1	0	0	0	0	0	0
57	40-60	0	0	0	1	0	0	0	0	0	0
58	40-60	0	0	0	1	0	0	1	1	0	0
59	40-60	0	0	1	1	0	0	0	0	0	0
60	60-100	0	0	0	1	0	0	0	0	0	-
61	40-60	0	0	2	0	0	0	0	1	0	0
62	40-60	0	0	0	1	0	0	1	1	0	0
63	40-60	0	1	1	1	0	0	0	0	0	0
64	40-60	2	1	0	2	1	0	1	1	0	1
65	40-60	0	0	0	1	0	0	0	0	0	0
66	>100	0	0	0	1	0	0	0	0	0	0
67	40-60	0	0	2	2	2	1	2	3	2	2
68	40-60	0	0	1	1	0	0	1	1	0	0

[1] <20, 20-40, 40-60, 60-100, >100

Appendix A

EPA-PHASE II

SITE VISIT REPORT SUMMARY
MAINTENANCE

Plant No.	Downtime Due To Inadequate Maintenance	Spare Parts Inventory or Accessibility	Back-up Units for Major Processes	Appearance of Plant and Grounds	Emergency Power Source	Maintenance References	Outside Contract Work	Records of Maintenance
01	0	0	0	0	No	0	< 10%	0
02	1	1	0	2	No	1	< 10%	0
03	0	1	0	0	Yes	1	20%	1
04	0	0	0	1	Yes	0	< 10%	0
05	2	2	0	1	No	0	< 10%	1
06	0	0	0	0	No	0	5%	0
07	1	1	0	0	Yes	0	< 10%	0
08	0	0	0	0	Yes 1	1	None	0
09	1	0	0	0	Yes	0	None	0
10	1	0	1	0	Yes 2	0	< 10%	0
11	3	1	0	2	Yes 2	2	None	2
12	1	1	0	0	No	0	< 10%	0
13	1	0	0	0	Yes	1	50%	0
14	1	1	0	0	Yes	1	< 10%	0
15	1	1	0	1	Yes	0	< 10%	0
16	0	1	0	1	Yes 1	1	2%	2
17	1	2	0	0	No	0	20%	1
18	1	0	2	0	Yes	2	< 10%	1
19	0	2	1	0	No	0	None	2
20	1	2	1	1	Yes	1	< 10%	0
21	2	2	1	0	Yes	0	< 10%	0
22	1	0	0	0	Yes	0	< 5%	0
23	0	2	0	0	Yes 2	2	5%	0
24	1	0	1	0	Yes	0	< 10%	0
25	0	1	0	0	Yes	0	5%	0
26	1	1	0	0	No	0	25-50%	0
27	1	1	0	0	Yes	0	5%	0
28	3	2	0	0	Yes 2	2	50%	0
29	2	2	0	1	No	2	50%	0
30	0	0	0	0	Yes	1	5%	0
31	0	0	1	0	No	1	None	0
32	1	1	2	0	No	0	None	0
33	2	2	0	0	Yes 2	0	<10%	1
34	2	1	0	0	Yes	0	<10%	0
35	1	0	0	0	No	0	<10%	0

Appendix A

EPA-PHASE II

SITE VISIT REPORT SUMMARY
MAINTENANCE (Cont'd)

Plant No.	Downtime Due To Inadequate Maintenance	Spare Parts Inventory or Accessibility	Back-up Units for Major Processes	Appearance of Plant and Grounds	Emergency Power Source	Maintenance References	Outside Contract Work	Records of Maintenance
36	1	1	0	1	Yes	0	<10%	0
37	0	0	0	0	No	0	5%	2
38	0	1	0	0	Yes	1	<10%	0
39	0	1	0	0	No	0	None	2
40	0	1	0	0	Yes 2	2	<10%	2
41	0	1	0	0	No	0	<10%	0
42	0	1	0	0	Yes	1	5%	2
43	0	1	0	0	Yes	0	<10%	0
44	0	1	0	0	Yes	0	1%	0
45	0	0	0	0	Yes 2	0	<10%	0
46	2	2	0	0	Yes	0	15%	2
47	0	0	0	0	Yes	0	<10%	0
48	0	1	0	0	Yes	1	<10%	0
49	1	0	1	0	Yes	1	<10%	0
50	1	2	0	0	Yes	0	15%	0
51	0	0	0	0	Yes	1	<10%	0
52	0	1	0	0	Yes	0	<10%	1
53	1	0	0	0	No	0	5%	0
54	3	2	0	0	–	2	<10%	2
55	1	0	0	0	No	0	5%	0
56	0	1	–	1	Yes	1	<10%	0
57	1	1	0	1	No	0	None	0
58	1	2	0	0	Yes	0	None	2
59	0	1	0	1	Yes	1	10%	1
60	1	1	0	0	Yes 2	0	1%	0
61	0	1	1	0	No	0	< 5%	0
62	1	1	0	0	Yes	0	<10%	0
63	1	1	1	0	No	0	<10%	0
64	2	2	1	1	Yes 2	0	10%	1
65	1	0	1	1	Yes	0	5%	0
66	1	0	0	0	Yes	0	<10%	0
67	1	1	1	0	No	0	None	1
68	0	1	0	0	Yes	0	5%	1

APPENDIX B

COMPOSITE PLANT EVALUATION SUMMARY

PLANT NUMBER	01	02	.00	10	14	15	16	19	23	24	27	28	33	38	41	48	56	58	61	62	64	65	67	POINT TOTAL	RANK	TIMES RANKED NO. 1
A. ADMINISTRATION																										
1. PLANT ADMINISTRATORS																					2		1	3		
a. POLICIES																					2		1	3		
b. FAMILIARITY WITH PLANT NEEDS	1			1																						
2. PLANT STAFF																										
a. MANPOWER								3					1		1			1		1	3			11		
1. NUMBER				1														1			0	2	1	6		
2. PLANT COVERAGE				1				1																		
b. MORALE							1											2			1			4		
1. MOTIVATION																							1	2		
2. PAY				1								1				1			2		1		2	6		
3. SUPERVISION				1								1									1		1	5		
4. WORKING CONDITIONS				1			1					2						2			2			6		
c. PRODUCTIVITY							2																1	1		
d. PERSONNEL TURNOVER																										
3. FINANCIAL																					3		1	7		
a. INSUFFICIENT FUNDING				1								2							2	1				3		
b. UNNECESSARY EXPENDITURES																										
c. BOND INDEBTEDNESS																										
B. MAINTENANCE																										
1. GENERAL							1			1		1						1			3			10		
a. HOUSEKEEPING	1											2				1								5		
b. EQUIPMENT AGE				1	1							2				1					2		1	9		
c. SCHEDULING & RECORDING				2		1							1								3			5		
d. MANPOWER				1																						
2. PREVENTIVE												2		1		1		1			3		1	12		
a. LACK OF PROGRAM	1			1			1					1				1					2		1	7		
b. REFERENCES AVAILABLE				1			1									2			1	1	3		1	14		
c. SPARE PARTS INVENTORY				1	1	1					1	2														
3. EMERGENCY										1		1		1		1					1		1	7		
a. STAFF EXPERTISE						1							1	1		1					3			10		
b. CRITICAL PARTS PROCUREMENT			1	1	1							1		1		1					3		1	10		
c. TECHNICAL GUIDANCE				2		1																				
C. DESIGN																										
1. PLANT LOADING												1		3	1		3							12		3
a. ORGANIC		1		3								3		1		3								13		
b. HYDRAULIC			2	2	1			1			1	1	2	3	1		3					1	2	20	6	2
c. INDUSTRIAL				3	3						1			1			1						2	6		
d. TOXIC				1										2		1								6		
e. SEASONAL VARIATION		1		2				3			2	3		1		3					1			10	10	3
f. INFILTRATION/INFLOW				2	1				3			3				2			2	1		2		16		
g. RETURN PROCESS STREAMS	1	1		1																						
2. UNIT DESIGN ADEQUACY												1		1		1								6		
a. PRELIMINARY				2		1																		7		1
b. PRIMARY				1		1						1				1										
c. SECONDARY																								14		
1. PROCESS FLEXIBILITY				2		1				2		3		1		2	2					1		23	4	1
2. PROCESS CONTROLABILITY		3	1	2			2	1	2	2		3		2	1	2							1	5		1
3. AERATOR											3			1			1							12		1
4. CLARIFIER				2			2					2		1		1				2			2			
d. ADVANCED WASTE TREATMENT																								7		
e. DISINFECTION				3								2	1			1										

PLANT NUMBER	01	02	09	10	14	15	16	19	23	24	27	28	33	39	41	48	56	59	61	62	64	65	67	POINT TOTAL	RANK	TIMES RANKED NO 1
2. UNIT DESIGN ADEQUACY - CONT.																										
f. SLUDGE WASTING AND RETURN	2	2		2			3	1		3		3	3	1		1					3	2		26	2	3
g. SLUDGE TREATMENT	2	1		1							1	3		1		1	1				3	1		15		
h. ULTIMATE SLUDGE DISPOSAL			1	1			1							1	1		2	1				2	1	11		
3. MISCELLANEOUS																										
a. ALARM SYSTEMS				1		1													1				1	4		
b. ALTERNATE POWER SOURCE						1		3						1	1				1		1			8		
c. PLANT LOCATION																							1	1		
d. PROCESS ACCESSIBILITY FOR SAMPLING														2										2		
e. EQUIPMENT ACCESSIBILITY FOR MAINTENANCE														1									1	2		
f. PLANT INOPERABILITY DUE TO WEATHER																1								1		
4. UNIT PROCESS LAYOUT																										
a. LACK OF UNIT BYPASS				2												1								3		
b. HYDRAULIC PROFILE																										
1. FLOW BACKUP				2	1							3												5		
2. SUBMERGED WEIRS				2								1												3		
3. FLOW PROPORTIONING TO UNITS						1								1										2		
c. UNIT ACCESSIBILITY														1										1		
d. PROCESS AUTOMATION																										
1. MONITORING				1																				1		
2. CONTROL			2	1								1												4		1
e. LACK OF STAND-BY UNITS FOR KEY EQUIPMENT*				2															1				1	4		
f. LABORATORY SPACE & EQUIPMENT				2						2		3		1	1	1					1		2	13		
B. OPERATION																										
1. STAFF QUALIFICATIONS																										
a. ABILITY																										
1. APTITUDE										3		1				1		1	1					7		
2. LEVEL OF EDUCATION				1						2		1				1		1			2		1	9		
b. CERTIFICATION																										
1. LEVEL OF CERTIFICATION										1														1		
2. TRAINING	1			1		1	1	3		3		1				1			2		2		2	18	9	
c. SEWAGE TREATMENT UNDERSTANDING	2			1			2	2		3		1		1		2		2	1		1		2	20	7	2
d. INSUFFICIENT TIME ON THE JOB (GREEN CREW)												2											1	3		
2. TESTING																										
a. PERFORMANCE MONITORING										3		2				1				1	1		2	10		
b. PROCESS CONTROL TESTING	3			2	2	1	1	1	1	3	1	2				1		1	1		1	1	2	24	3	
3. PROCESS CONTROL ADJUSTMENTS																										
a. OPERATOR APPLICATION OF CONCEPTS AND TESTING TO PROCESS CONTROL	3			2	2	3	2	3		3	1	3		2	1	2		1	3		1	1	2	35	1	4
b. TECHNICAL GUIDANCE	2	2		2	1	1		2		1		2		1		1			2		2		2	21	5	
4. O & M MANUAL																										
a. ADEQUACY	1	1		2	1	2	1				1			2			3			1	5		2	20	8	
b. USE BY OPERATORS	1			2	1	1								1					2		3			11		
5. MISCELLANEOUS																										
a. EQUIPMENT MALFUNCTION				1		3						1									3			8		1
b. SHIFT STAFFING ADEQUACY				1																				1		